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（出國類別：實習）

赴美實習『國際HF監測系統』報告書

行政院研考會/省(市)研考會 總號欄

服務機關:交通部電信總局
出國人員:中區電信監理站王瑞琦
出國地點:美國
出國日期:92 年 12 月 4 日至 12 月 14 日
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「國際 HF 監測系統」之研究實習

主辦機關:

交通部電信總局

聯絡人／電話:

李菲菲／02-23433679

出國人員:

王瑞琦　交通部電信總局　中區電信監理站　科長

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關鍵詞: 監測系統,電波能量偵測,頻譜監測,HF 接收系統,TCI 402-3,系統靈敏度,信號雜音比,天線極化效應

內容摘要: 近幾年多元社會及通信新紀元之來臨，各種頻率在有限的空中互相交錯爭道，導致電波秩序異常的壅塞紊亂。交通部電信總局有鑒於此，對於無線電頻率的有限資源，如何去蕪存菁，整合各個重複浪費的頻段，規劃合理且有效率的重複使用等等需求，擬定了『電波能量偵測計劃』，希望能有效的管理電波秩序，取締非法發射，保障合法發射者權益，並期能更進一步的整合各項無線頻譜資源，達到最有效率之應用，以促進資訊匯流社會之發展。『國際 HF 監測系統』係『電波能量偵測計劃』中之一環，並同步與世界上各主要先進國家共同合作，爲區域的頻譜監測貢獻心力。此一系統係由美國 TCI(Technology for Communications International)公司所得標建設，本報告書分就『HF 接收系統』與『HF DF 系統靈敏度分析』兩大方向，約略探討『國際 HF 監測系統』內的核心要素--天線的種種相關技術要素。

目次

壹、 前言

近幾年由於社會環境的變遷，各種通信方式推陳出新，民眾使用各式各樣無線電器材，合法或非法發射電波，與行動電話通信業者、公民營機構、軍警頻道、航空頻道、廣播頻道等等在有限的空中互相交錯爭道，導致電波秩序異常的壅塞紊亂。加上最近幾年各項電信業務開放後，電信服務進入多元競爭時代，數位匯流之趨勢接踵而至，各種無線加值服務如雨後春筍般一一出現，對於無線電頻率的有限資源，如何去蕪存菁，找出閒置不用的，整合各個重複浪費的頻段，規劃合理且有效率的重複使用，已成為政府相關單位最急迫的任務之一。交通部電信總局有鑒於此，擬定『電波能量偵測計劃』，從頻譜監測開始，描繪空中頻繁的交通圖譜作為基礎工具，希望能有效的管理電波秩序，取締非法發射，保障合法發射者權益，並期能更進一步的整合各項無線頻譜資源，達到最有效率之應用，以促進資訊匯流社會之發展。

『國際HF監測系統』係『電波能量偵測計劃』中之一環，並同步與世界上各主要先進國家共同合作，為區域的頻譜監測貢獻心力。此一系統係由美國TCI(Technology for Communications International)得標負責建設，目前已到達完工驗收之階段，為期針對此一系統有更進一步之了解，完成後能儘速運用與維護，特派本人前往該公司研究實習。

貳、 行程紀要

本案研究實習期間含行程共計十一日，從九十二年十二月四日至十二月十四日：

十二月四日：台北 ＞舊金山

十二月五日：TCI 工廠參訪及系統介紹

十二月八日至十日：HF 監測系統課程與實習

十二月十一日至十二日：HF DF 系統課程與實習

十二月十三日至十四日：舊金山＞台北

參、 實習報告

一、HF 接收系統(HF Receiving System-HFRS)

本系統提供HF接收系統之整體解決方案，並就各個方法之間，比較其優劣，以作為決策或系統選擇、設定之參考。

HF接收系統，包含了一組天線陣列、射頻信號分配器、射頻信號交換器，及射頻電纜配線系統以提供信號給一群『高頻信號接收器』之輸入端。另外若是天線陣列距離監視設備有數公里之遙，則需配備額外一組增益器。

所有的HF接收系統零組件皆能以最精密靈敏之狀態，提供動態彈性之工作範圍，以配合系統之整體性能。但是最終能決定整個系統靈敏度的，還是在於天線的選擇上面。因此基本上本章主要課題在於討論天線的選擇及其造成之影響。

天線的選擇

天線的主要性能需求，在於能夠提供靈敏的高頻信號接收，涵蓋三百六十度水平覆蓋範圍，使得從最近的信號乃至於幾千公里遠的高頻信號發射都能接收得到。

很顯然的，要達到這樣的性能要求，必須對許多的天線參數諸元做考慮與取捨。

天線參數包含：

- 頻率範圍：
  - 低頻
  - 高頻
- 水平涵蓋範圍：
  - 三百六十度全向性
  - 定向性
- 垂直涵蓋範圍：
  - 傳播距離
  - 極化
- 系統靈敏度
  - 天線雜音係數
  - 射頻環境因數
- 系統擴充性

這樣的性能要求：高靈敏的信號接收，涵蓋全方位三百六十度水平接收範圍，意味著我們需要用到多環型、高增益的對數週期化天線陣列。而且為了要符合 1.5 到 30 MHz 全頻接收頻率覆蓋範圍，TCI 選用了 410 系列天線如下：

一組由二十個偶極化 410-2 型天線之陣列或

一組由二十個偶極化 410-3 型天線之陣列或

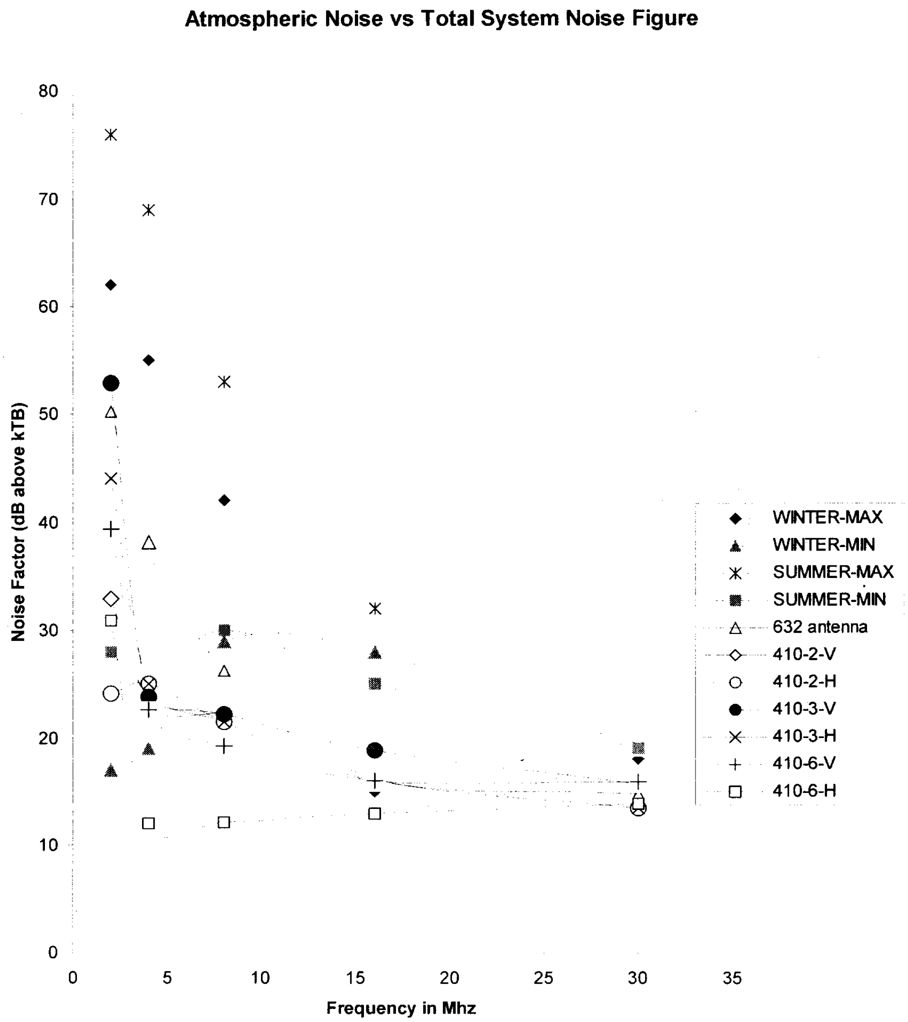
一組由二十四個偶極化 410-6 型天線之陣列

這些天線陣列的性能諸元如下表：

	Twenty element 410-2	Twenty element 410-3	Twenty four element 410-6
Number of Elements	20	20	24
Frequency Range	1.5-30 MHz	1.5-30 MHz	1.5-30 MHz
Polarization	Vertical & Horizontal	Vertical & Horizontal	Vertical & Horizontal
Directive gain	9-17 dBi	9-17 dBi	11-19 dBi
Azimuth Beamwidth	~60° to ~22°	~90° to ~22°	~32° to ~15 °
Elevation Take-off Angle	60° to 25°	60° to 25°	48° to 15°
System Sensitivity (10 dB SNR in 3 kHz bandwidth)	-25 to –12 dBuV/m	-25 to –10 dBuV/m	-26 to –17 dBuV/m
Application	Short/Medium Range 0-2500 km	Short/Medium Range 0-2500 km	Medium/Long Range 500 - 4000 Km
Suitable for Direction Finding (DF)	YES	YES	YES
Suitable for DF with Single Site Location (SSL)	YES	YES	YES
Environment	160 km/h wind, no ice	160 km/h wind, no ice	225 km/h wind, no ice
Installation Area Required for all Antennas	300mx300m for 410-2 antenna	215mx215m for 410-3 antenna	350mx350m for 410-6 antenna
Antenna Height	41 m 410-2	29 m 410-3	41 m 410-6
Compatible with RF Distribution	Yes, requires distribution of 42 antenna outputs: -40 directional -1 omni (hor. pol) -1 omni (ver. pol)	Yes, requires distribution of 22 antenna outputs: -40 directional -1 omni (hor. pol) -1 omni (ver. pol)	Yes, requires distribution of 50 antenna outputs: -48 directional -1 omni (hor. pol) -1 omni (ver. pol)

天線性能比較：

下圖顯示出這三種天線組態的雜音 v.s. 頻率的比較：



從上圖我們可以得知 410-6 及 410-2 系列在低頻的表現要比 410-3 系列要好一些。這個結果跟原先的推測相去不遠，因為 410-2

系列為 HF 全頻天線，而 410-6 系列是中至長距離範圍之天線。在短至中距離範圍，410-2 系列有最優異的表現，幾乎比 410-3 系列在低頻方面好上 20dB。這要歸功於其天線組額外加長的天線長度，有利於低頻段的接收。

接收角度因素:

天線可以用涵蓋距離的範圍大小來分類：從小於 500 公里短距，500-2500 公里的中距，到大於 2500 公里的長距型天線。造成這些距離最主要的因素是接收信號的仰角。對短距接收而言，典型的接收天線仰角大約是 60 到 90 度的範圍，而長距離的角度約是 10 到 30 度。因此，一個理想的天線應該能有固定的場型圖來涵蓋 0 到 90 度的全範圍。在我們的 410-2 與 410-3 系列是屬於短程至中程距離的天線，角度介於 25 到 60 度之間，而 410-6 系列是屬於中至長程的天線，接收天線角度介於 15 到 48 度之間。

定方向及信號源定位能力：

410 系列天線，加上一些額外設備之後，有極佳的定方向及信號源定位能力，且能提供靈敏的 HF 天線作為接收監視器分析及方位尋找。

二、HF DF 系統靈敏度分析

2.1 簡介

本章主要是探討採用 TCI 402-3 型號之天線陣列組為主的 DF 系統，其測定系統靈敏度的方法，並求得水平天線陣列靈敏度的數值，以和單一未極化天線(鞭形垂直天線)做一比較。同時也對信號雜音比的定義以及它與頻帶寬度的相依程度作一概括性討論。

第二節將討論計算系統靈敏度實用性的原理與假設。並解釋內部雜音受限系統(Internal noise limited system)與外部雜音受限系統(External noise limited system)之異同。第三節將描述天線靈敏度與天線極化對整個系統靈敏度的影響。天線極化尤其是討論的重點，因為一組水平極化後的天線能抗阻 16-20 分貝的外部雜音，對提昇系統靈敏度有極大助益。

第四節將對各種天線元件之系統靈敏度計算的綜合效應作一結果總和。

連結 TCI 天線群 402-3 陣列的 TCI DF 系統，以數位信號處理技術，以及 WFA DF Algorithm 程式，能提供其他 DF 系統所無法提供的搜尋結果。TCI DF 技術能有效的應用接收到的微弱信號，在第五節中將列示甚至微弱到在 3KHz 頻寬,信號雜音比為-10 分貝的

信號，如何被有效的檢測出來。

2.2 系統靈敏度計算

DF 系統的靈敏度定義是:當一個信號能足以讓 DF 接收器達到其設定的精確度時，在天線陣列上之電場強度(uV/m 為單位)。對於 TCI DF 系統來說，當信號雜音比在 3KHz 的帶通頻寬下是 10 分貝或更高時，設定為其精確度達到之標準。因此，其靈敏度可以定義為：能使得在接收器上，在 3kHz 頻寬帶上產生 10 分貝的信號雜音比值，所需之信號之電場強度。

在接收器上的信號雜音比由下列各項因素決定：

- 接收信號強度：包括所有增益或衰減因素如天線、放大器、功率放大、電纜損失等。
- 外部雜音：同時被天線射頻系統所接收，並被同樣的增強或衰減。
- 內部雜音：因為系統內部元件產生的雜音，被傳達到接收器前端。

在接收器量測到的雜音包含內部及外部雜音之總和。而系統所要的信號則由第一項所決定。信號雜音比即是第一項強度與二、三項強度的比值。TCI 系統工程師用一套獨有的程式 DYNRANG 來計算系統的靈敏度。

一套好的射頻系統應該使內部雜音的產生遠低於外部雜音。如此的系統可以稱為外部雜音受限系統(External noise limited system)，這樣的一個系統能得到最佳的性能，因為加上更多的放大器也不會增加信號雜音比值，因為外部的信號與雜音都會被放大器等量的放大。

而一套差的射頻系統內部雜音的產生卻高於外部雜音。如此的系統可以稱為內部雜音受限系統(Internal noise limited system)，亦即，內部產生的雜音大於外部接收到的，這是因為在射頻傳送路徑上沒有足夠的增益，或是內部元件不良或設計不佳產生過多的電子雜音所造成。這樣將使得信號雜音比值變差，產生在接收器端所量測的信號雜音比卻比天線端得到的信號雜音比值還差。要改善這樣的系統，最簡單的方法可以增加額外的放大器，而同時避免產生內部額外的相互調變，直到外部雜音準位提升到比內部雜音還高，如此一來，就可以將此內雜音受限系統轉換為外雜音受限系統。

所有 TCI DF 系統以及射頻分配系統，都依循這樣的原則，仔細的設計以避免內雜音系統的發生。

2.3 天線對系統靈敏度的影響

天線是一套 DF 系統最前端的元件，因此對於整體系統靈敏度的影響佔有重大的份量。天線對系統靈敏度的影響可以分兩方面因素討論，分別是Ａ：天線靈敏度以及Ｂ：天線極化，分別討論如下：

2.3.1 天線靈敏度的效應

TCI 的 402-3 系列天線有絕佳的靈敏度。其水平極化天線群能在很低的場強下提供足夠的電壓值。其他的天線元件，例如鞭形天線，與之相較不但規格小很多，靈敏度也無法比擬。

表格 2.3 綜合了這兩種天線的型態，以天線雜音強度圖作為比較。以 402-3 系列水平極化天線陣列，對應一組五米長，頻率範圍從 3 到 20MHz 的鞭形天線做比較。天線雜音強度圖與天線的靈敏度有極大的關聯性，可以代表著一組特定的天線轉換電場強度為纜線電壓之能力的一種標準量測方法。天線雜音強度圖尤其是在作為不同型態之天線的比較時很有用處。本表指出，當一個特定的 3mHz 信號抵達天線端的時候，鞭形天線的反應強度比 402-3 陣列天線低了 33 分貝。

頻率 MHz	水平陣列天線	鞭形天線
3.0	1.0 dB	34.0 dB
5.5	0.0 dB	19.0 dB
10.0	0.5 dB	12.0 dB
15.0	1.0 dB	3.8 dB
20.0	1.5 dB	3.5 dB

表格 2.3　天線雜音強度比較圖

這表示，若是 DF 系統採用鞭形天線，除非是外部的雜音水平超越了鞭形天線內部雜音強度，否則系統將自動的形成一個內雜音受限系統。

2.3.2 天線極化效應

天線的極化在 DF 系統的性能表現上，有很實際的作用。大部分的天波傳播信號，不論對水平極化或垂直極化天線，都有混合的極化效果反應。電磁波的行為模式畢竟不一樣。絕大部分的人為雜音信號，及一大部分的大氣雜音信號都是垂直極化的。上表的所有的雜音量測都以垂直天線元件為基準，因此，水平陣列天線如 402-3 系列的優勢便顯示出來了，它能夠抵抗掉通常會被垂直天線照單全收的 16-20 分貝的外部雜音，這表示，如果一個信號能在水平天線陣列給出 10 分貝或更好的信號雜音比值的話，同樣的信號可能在

垂直極化天線上產生一堆雜音而埋沒了真正的信號。因此，水平極化天線用在微弱信號的監聽及方位尋找系統上，比起被雜音蓋住的垂直天線來說，特別具有效率。

2.4 系統靈敏度比較

針對兩種型態的天線，把所有放大器、功率增益、損失、內部雜音及射頻分配器互調變副產品效應都計算在內，並假設如下兩種情況下做比較：

a) 系統靈敏度定義為：能使得在接收器上，在 3kHz 頻寬上產生 10 分貝的信號雜音比值，所需之信號的電場強度。

b) 假設沒有外在雜音。

根據這兩種天線的系統靈敏度計算列示如 4-1 表，可以看出，402-3 陣列天線能提供優於鞭形天線達 18.6 分貝的靈敏度。

Frequency	Sensitivity(dB uv/m)	Sensitivity(dB uv/m)
MHz	5m Monopole Antenna	402-3 Antenna
2	-0.8	-10.5
4	-6.8	-25.4
8	-12.7	-23.5
16	-16.6	-23.7
30	-12.5	-21.2

表 2.4：系統靈敏度定義為：能使得在接收器上，在 3kHz 頻寬產生 10 分貝的信號雜音比值，所需之信號之電場強度。

上表顯示出在頻率範圍 2-30 MHz，沒有外部雜音的情況下，產生 10 分貝的信號雜音比值所需的信號強度，從這裡可以看出 402-3 陣列所佔的優勢，能比鞭形天線接收到微弱許多的信號。

簡單的說，若是一個 DF 系統配備不好的或不靈敏的天線，將無法偵測到另外使用靈敏度高的天線所能偵查到的微弱信號。

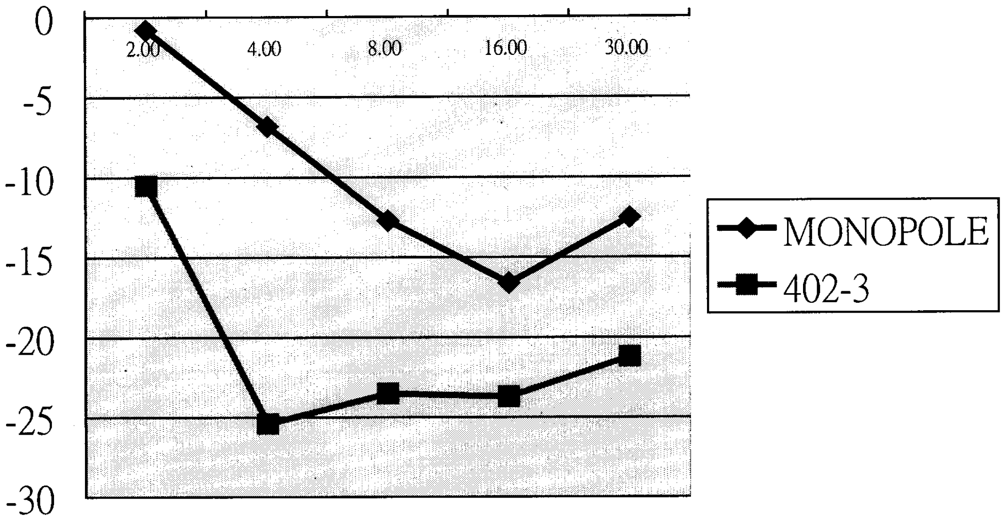


圖 2.4 兩種天線型別之系統靈敏度比較圖

2.5 信號雜音比之定義

信號雜音比之定義主要是決定於處理頻寬或是 DF 計算頻寬的選擇。大部分的 DF 系統需要最少接收之信號能提供 10 分貝之信號雜音比，才能足夠用以計算其到達之角度。對 一般 HF 的通信信號來說，其能量可能分布在整個 3KHz 頻寬內，例如 SSB 話音或是 MUX 信號。如此情況下，DF 的計算必須涵蓋到整個 3kHz 頻寬內，因此最小的 SNR 值訂定為在 3KHz 頻寬為 10 分貝。

TCI DF 系統以數位頻譜分析接收帶通信號，其分析的基本單位大小視是否有足夠資料取樣處理時間而定；標準的處理是以 200Hz

的 bin size 以及 200 msec 的 Integration time。這樣的信號，需要在 3kHz 頻帶有 10dB 的 SNR，在任何 bin size 上都需 10 dB。

有些特殊情況下，當被處理的信號集中在很窄的頻率範圍內時，在有足夠長的時間作 Integration 時，可以容許更低的 SNR，像是有些穩定的 CW 信號就是一例。

當在 3K 頻帶寬上作整合處理時，量測的 SNR 等於-10dB。但當使用 25Hz bin size 以及 3 sec 的 integration time 時，DF 處理程式能有 22 dB 的處理增益值，所以 DF 的計算能達到 12dB 的性能。這表示對窄頻信號而言，假設有足夠的 integration time 以容許更小的 bin size ，則 TCI DF 系統能在信號源 SNR 等於 10 分貝的 3KHz 頻寬下，提供一個不錯的方位資料結果。

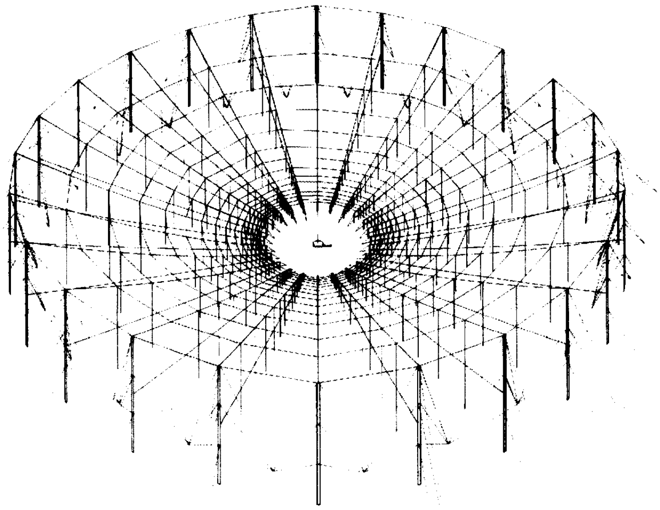
TCI DF 系統使用最新進步的數位信號處理技術，以求能儘可能的從不論多麼微弱的信號之中，萃取出最多的資訊。只要達到最低需求的資訊量，TCI DF 系統就能提供比其他定位系統更優異的定位結果。

TCI
A Dielectric Company

MODEL

402/410

HF Horizontally and Dual-Polarized High-Gain Receiving and DF CDAAs



The TCI 402/410 series of circularly disposed antenna arrays (CDAAs) uses a set of high-gain beams covering the full 360° azimuth to provide very sensitive HF signal reception and direction finding (DF) in a single structure. The 402 and 410 series log-periodic antenna arrays offer the ultimate for short/medium-range or medium/long-range reception and DF. The 402 is horizontally polarized; the 410 is dual polarized.

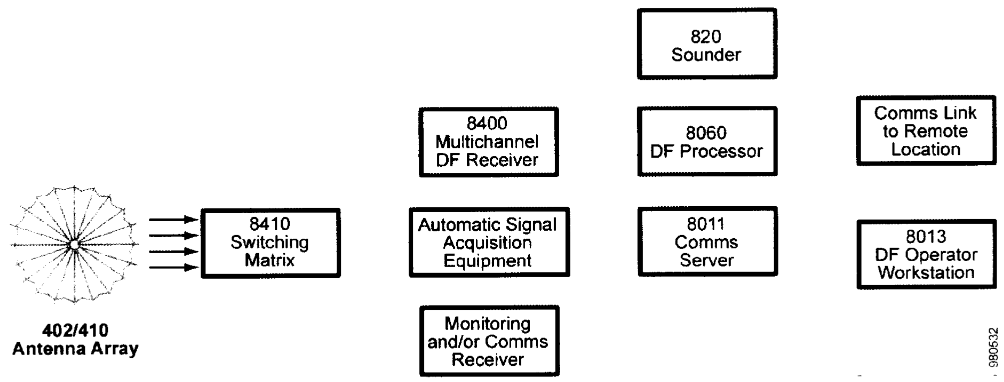
In receiving applications, the 402/410 CDAAs require significantly less space than a group of full-band, high-gain log- periodic antennas providing complete azimuth coverage. This makes the 402/410 highly advantageous when available land is limited or real estate at a premium. A set of 20 or 24 evenly spaced beams ensures exceptionally sensitive receiving coverage at all azimuth angles. Directive gains of up to 19 dBi are available. Omnidirectional and 60° azimuthal beams are options.

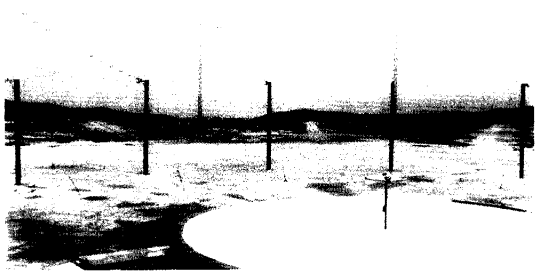
In DF applications, the 402/410 provides signal acquisition and DF with 1.6° rms azimuth accuracy, the limit achievable in ionospheric propagation. The 402 horizontal array is the most sensitive of all circularly disposed antenna arrays; other CDAAs are vertically polarized and experience higher received radio noise. The 402 is cross polarized to vertically polarized man-made noise. Field measurements show that the 402 receives much less atmospheric noise than vertically polarized monopoles. Sensitivity measurements on the TCI Model 402 show outstanding improve-ments of up to 20 dB over typical vertically polarized systems.

- **The ultimate in HF signal sensitivity**
  - *Acquisition*
  - *Monitoring/Communications*
  - *DF*
- **Exceptional DF accuracy**
- **Single Site Location (SSL) capability**
- **Short, medium, and long range**
- **Very efficient land use**

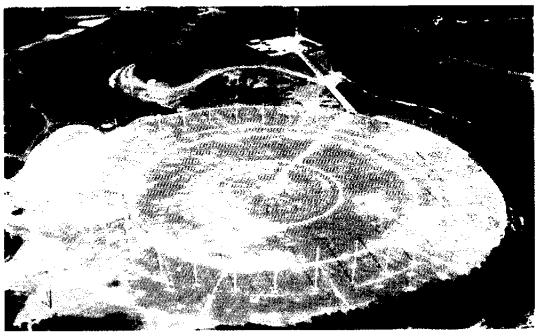
The Models 402-2 and 402-3 are short/medium-range antennas with good overhead coverage, which makes them excellent choices for Single Site Location (SSL) applications. The TCI 802 HFDF system uses the 402-2 or -3 to measure the elevation and azimuth angle of arrival. The 802 system then uses additional ionospheric height measurements, provided by the TCI 820 Vertical Incidence Sounder, to determine HF emitter location. SSL accuracy is ±25 km at 0–200 km from the SSL site and 12% rms at 200–1000 km.

Typical TCI Acquisiton, Monitoring and DF Application





402 Horizontal Antenna Array
A central underground operations room houses all electronic equipment components.



410 Antenna Array

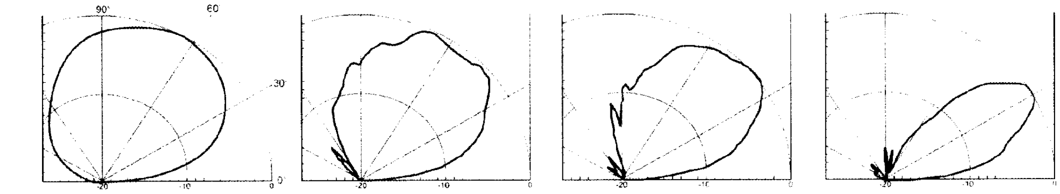
Antenna Performance

	Model 402-2 Model 410-2	Model 402-3 Model 410-3	Model 402-6 Model 410-6
Number of Elements	20	20	24
Frequency	1.5 to 30 MHz	1.5 to 30 MHz	1.5 to 30 MHz
402 Polarization	Horizontal	Horizontal	Horizontal
410 Polarization	Vertical and Horizontal	Vertical and Horizontal	Vertical and Horizontal
Directive Gain	9 to 17 dBi	9 to 17 dBi	11 to 19 dBi
Azimuth Beamwidth	60 to 22 degrees	90 to 22 degrees	32 to 15 degrees
Elevation Take-off Angle	60 to 25 degrees	60 to 25 degrees	48 to 15 degrees
Environment	160 km/hr no ice	160 km/hr no ice	225 km/hr no ice
Height	41 meters	29 meters	41 meters
Diameter	300 meters	215 meters	350 meters
Sensitivity (10 dB SNR in 3 kHz bandwidth)	–25 to –12 dBμV/m (typical system)	–25 to –10 dBμV/m (typical system)	–26 to –17 dBμV/m (typical system)
Sensitivity (10 dB SNR in 3 kHz BW) with no external noise	For 402-2 HP only –33 to –26 dBμV/m (typical system)	For 402-3 HP only –28 to –16 dBμV/m (typical system)	For 402-6 HP only –44 to –27 dBμV/m (typical system)
Application	Short/Medium Range 0 to 2500 km	Short/Medium Range 0 to 2500 km	Medium/Long Range 500 to 4000 km

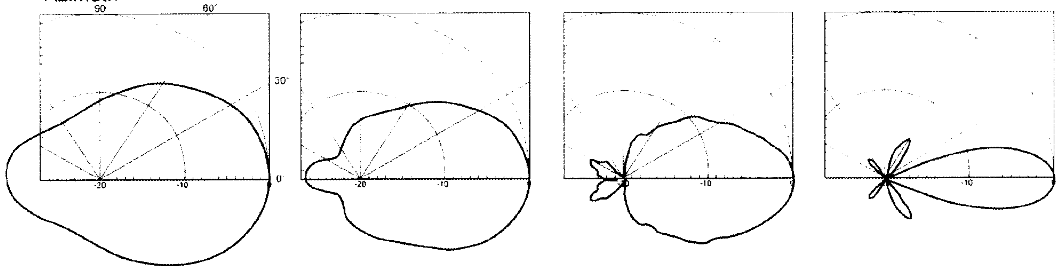
Beam Radiation Patterns*: Horizontal Sub-Array

Models 402-2, 402-3, 410-2, and 410-3 (Horizontal Polarization)

Elevation



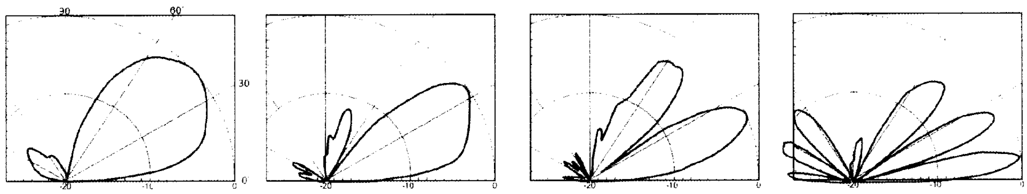
Azimuth



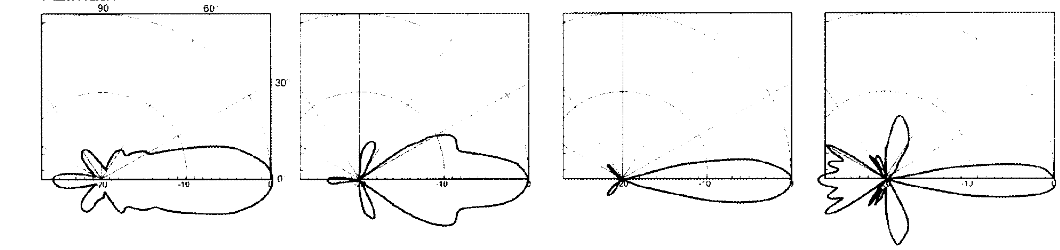
At 60° elevation	At 65° elevation	At 40° elevation	At 35° elevation
4 MHz	8 MHz	14 MHz	28 MHz
11.1 dBi**	12.3 dBi	13.3 dBi	17.4 dBi

Models 402-6, and 410-6 (Horizontal Polarization)

Elevation



Azimuth



At 40° elevation	At 35° elevation	At 25° elevation	At 10° elevation
4 MHz	8 MHz	14 MHz	28 MHz
14.6 dBi**	16.1 dBi	17.8 dBi	17.2 dBi

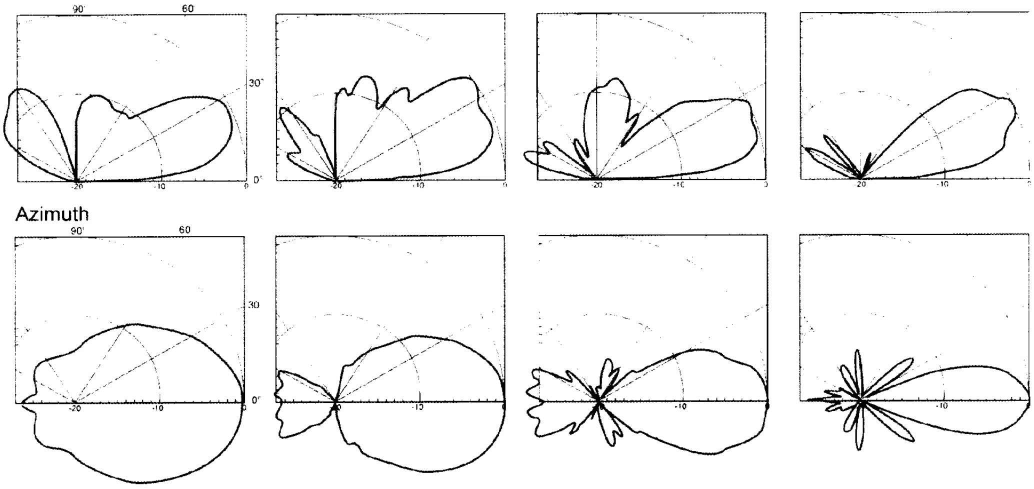
* Plotted in dB relative to beam maximum

** Directivity is given for beam maximum

14.6 dBi** 16.1 dBi 17.8 dBi 17.2 dBi

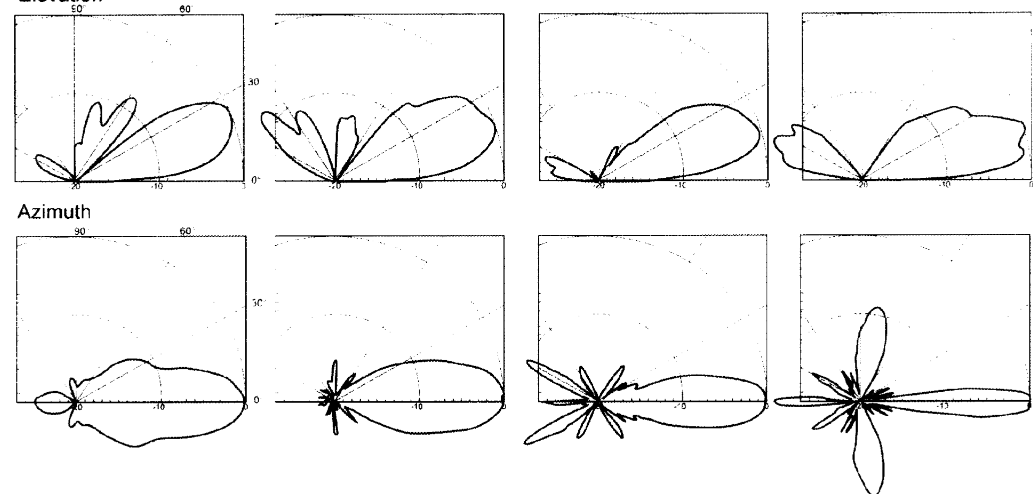
Beam Radiation Patterns*: Vertical Sub-Array

Models 410-2, and 410-3 (Vertical Polarization)



At 25° elevation	At 35° elevation	At 25° elevation	At 25° elevation
4 MHz	8 MHz	14 MHz	28 MHz
12.0 dBi**	12.8 dBi	13.8 dBi	16.8 dBi

Models 410-6 (Vertical Polarization)



At 25° elevation	At 20° elevation	At 20° elevation	At 20° elevation
4.0 MHz	8 MHz	14 MHz	28 MHz
14.9 dBi**	14.8 dBi	17.3 dBi	17.2 dBi

* Plotted in dB relative to beam maximum

** Directivity is given for beam maximum

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TCI
A Dielectric Company 47300 Kato Road, Fremont, California 94538, USA • 1 800 824-8074 (USA) • Tel 1 510 687-6100 • Fax 1 510 687-6101

Proposal for HF Receiving System

January 2002

Introduction

This proposal presents several alternative solutions for an HF Receiving System (HFRS), and provides the explanation of trade-offs between those different solutions. The HF Receiving System includes an antenna array, RF distribution, RF switching and cabling necessary to provide RF inputs for a large number of HF receivers. There is also an added complexity due to the fact that the antenna array is located several kilometers away from the monitoring facility.

All of the HFRS components contribute to the overall system performance in terms of sensitivity and dynamic range, but it is the choice of the antenna that ultimately determines the system sensitivity. Based on that, this proposal first deals with the antenna selection, followed by the discussion about the effects of RF distribution, RF switching and cabling choices.

Antenna Selection

The requirements for the antenna are to provide very sensitive HF signal reception, with full 360° azimuth coverage, for HF signals transmitted from distances ranging from nearby to thousands of kilometers. Clearly, to achieve this type of performance it is necessary to consider a multitude of antenna parameters, and carefully examine the tradeoffs between those parameters.

Antenna parameters include:

1. Frequency Range
    a) Low frequency
    b) High Frequency

2. Azimuth Coverage
    a) 360° azimuth coverage
    b) Directivity

3. Elevation Coverage
    a) Propagation Distances
    b) Polarization

4. System Sensitivity
    a) Antenna Noise Factor
    b) Environment RF characteristics

5. System Expandability

The requirement for high sensitivity and full 360° azimuth coverage dictates an antenna configuration that uses multiple circularly disposed, high-gain, log periodic antennas. Based on requirements, and in conjunction with the requirement for full frequency coverage from 1.5 to 30 MHz, TCI recommends the following antenna configurations:

- Inward facing array of eight horizontal 548-3 log periodic antennas
- Outward facing array of eight horizontal 548-3 log periodic antennas
- Inward looking array 402-3 consisting of 20 horizontal log periodic antennas

The performance characteristics of these antennas are summarized in the following table:

	Inward looking eight element 548-3	Outward looking eight element 548-3	Inward looking twenty element 402-3
Number of Elements	8	8	20
Frequency Range	1.5-30 MHz	1.5-30 MHz	1.5-30 MHz
Polarization(1)	Horizontal	Horizontal	Horizontal
Directive gain	7-12 dBi	11-12 dBi	11-12 dBi
Front-to-Back Ratio	>4 dB	>12 dB	>12 dB
Azimuth Beamwidth	~70° to ~30°	~70° to ~30°	~70° to ~20°
Elevation Take-off Angle	20° to 60°	20° to 60°	20° to 90°
System Sensitivity (10 dB SNR in 125 Hz)(2)	-50 dBu to –35 dBu	-50 dBu to –35 dBu	-38 dBu to –24 dBu
System Noise Figure(2)	36 to 14 dB	36 to 14 dB	44 to 14 dB
Application	Medium Range 500-2500 km	Medium Range 500-2500 km	Short to Medium Range 0-2500 Km
Omnidirectional Coverage with Horizontal Polarization	Requires a separate antenna TCI Model 530-3	Requires a separate antenna TCI Model 530-3	Included
Omnidirectional Coverage with Vertical Polarization for Ground Wave Reception	Requires a separate antenna TCI Model 638-2	Requires a separate antenna TCI Model 638-2	Requires a separate antenna TCI Model 638-2

Suitable for Direction Finding (DF)[3]	NO	NO	YES
Suitable for DF with Single Site Location (SSL)[4]	NO	NO	YES
Optional High Directivity Beams[5]	NO	NO	YES, directivity up to 18 dBi
Environment	160 km/h wind, no ice	160 km/h wind, no ice	160 km/h wind, no ice
Installation Area Required for all Antennas	250mx250m for 548-3 antenna 91mx91m for 530-3 antenna 15mx15m for 638-2 antenna Total installation area 500mx500m with clearance area[6]	350mx350m for 548-3 antenna 91mx91m for 530-3 antenna 15mx15m for 638-2 antenna Total installation area 600mx600m with clearance area[6]	215mx215m for 402-3 antenna 15mx15m for 638-2 antenna Total installation area 450mx450m with clearance area[6]
Antenna Height	40 m 548-3	40 m 548-3	29 m 402-3
Compatible with RF Distribution	Yes, requires distribution of 10 antenna outputs: -8 directional -1 omni (hor. pol.) -1 omni (ver. pol.)	Yes, requires distribution of 10 antenna outputs: -8 directional -1 omni (hor. pol.) -1 omni (ver. pol.)	Yes, requires distribution of 22 antenna outputs: -20 directional -1 omni (hor. pol.) -1 omni (ver. pol.)

(1) Polarization for sky wave reception. For ground wave, that is vertically polarized, there is a separate antenna.

(2) System noise figure and sensitivity are based on the similar RF distribution and switches connected to all antenna types, to allow the comparison of the antenna performance.

(3) Model 548-3 antenna array cannot be configured and/or modified to be suitable for DF use. Model 402-3 is specially designed to be suitable for DF.

(4) Model 402-3 is specially designed to be suitable for SSL operation.

(5). Model 402-3 can be optionally connected to the beamformer units that provide narrow highly directive monitoring beams.

[6] Total Installation area accounts for the spacing between various antennas and clearance to the nearby structures.

Antenna Patterns Comparison

The elevation and azimuth patterns for three antenna configurations: inward looking 8 element 548-3 array, outward looking 8 element 548-3 array and 20 element inward looking 402-3 array (both element and beam) are shown below. Figure 1 shows comparison of elevation patterns for a standalone 548-3 antenna, and both inward and outward looking arrays consisting of eight 548-3 antennas.

Figure 2 shows the azimuth patterns for outward looking configuration of eight 548-3 antennas, and Figure 3 shows the azimuth patterns for the inward looking configuration of eight 548-3 antennas.

Figures 4 and 5 illustrate 402-3 patterns for both individual antennas and directive beams. The beams are created using optional TCI Model 8507 Beamformer that combines outputs of six adjacent antenna elements.

It is clear from the pattern data that the performance of outward looking array of eight 548-3 antennas is the same as the performance of a standalone 548-3 antenna. At the same time, the pattern data indicates that the inward looking configuration of eight 548-3 antennas exhibits both loss of directivity and decrease in front-to-back ratio compared to a standalone 548-3 antennas.

For these reasons the outward looking configuration is a preferred solution if 548-3 antenna is used.

The azimuth pattern comparison between the outward looking 548-3 array and 402-3 array shows that 402-3 array has higher directivity (by about 2-3 dBi) at frequencies above 4 MHz, and the azimuth beamwidth (-3 dB point) is about 30% less (narrower beamwidths provide better suppression of signals from unwanted directions).

402-3 array has higher directivity and narrower beamwidth above 4 MHz than 548-3 array.

NOTE: Although the optional directive beams for 402-3 array require more complex RF distribution, the beams provide yet another 2-3 dBi increase in the directivity over element 402-3 array, and further narrowing of the beamwidth.

Elevation Patterns

Antennas can be categorized, in terms of coverage range, as short range (<500 km), medium range (500km to 2500km), and long range (> 2500km) types. Basic difference between these ranges is the elevation (take-off) angle of the received signal. For short ranges the take-off angle is typically 60° to 90°, whereas the take-off angle for the long range is typically 10° to 30°. Therefore, an ideal antenna would have an elevation pattern that would be constant from 0° to 90°.

Figure 6 shows the expected values of the take-off angle for various transmitter distances (100, 500, 1000, 2000, 3000 and 4000 km), as a function of frequency and time-of-day. The expected values of take-off angles vary from almost 90° for close in transmitters to <20° for long range transmitters (>3000km). Both 548-3 and 402-3 antenna elevation patterns cover those elevation ranges, but 402-3 antenna has significantly better performance for the close in targets. For example, at 3 MHz 402-3 antenna directivity at 90° take-off angle (elevation) is down only by 5 dBi from its maximum directivity, whereas 548-3 directivity is down by 25 dBi from its maximum directivity. The difference in directivity relates directly to the system sensitivity, so the 548-3 array will have a 25 dB reduction in the sensitivity for close in targets.

402-3 array has better sensitivity performance for short range signals than 548-3 array.

System Noise Factor

For a particular antenna configuration (including the RF components following the antenna) it is possible to calculate the operating noise factor. Note that the noise factor determines the amount of signal power needed to produce the required signal – to–noise ratio (SNR) in a given bandwidth. It can be shown that the total noise factor of the receiving system f is given as:

$$f = f_a - 1 + f_{RF} \qquad (1)$$

where f_a is the amount of external noise and f_{RF} is the noise factor of the antenna and RF components (loss in available power). The external noise itself has various components such as atmospheric, galactic and man-made noise. Figure 7 shows atmospheric noise factor (four curves for high and low sunspot number in summer and winter), man-made noise (three curves for different environments), and three antenna noise factors (402-3 element, 548-3 and 632 short monopole). Note that the galactic noise is not presented because its effect in the HF band is negligible. The noise factor data for the Model 632 antenna, which is a 15' whip antenna, is shown for reference purposes.

Note that the antenna noise factor was calculated using a simple RF distribution consisting of cable, RF switch and the receiver. Although any changes in the RF components will change the noise factor, the noise factor change can be made the same for all antennas. This allows us to compare only the antenna effects on the noise factor.

From Formula (1) it is evident when $f_a >> f_{RF}$ the antenna noise factor f_{RF} does not contribute to the total noise factor f, making the receiving system externally noise limited. In the case when $f_{RF} >> f_a$ the system is internally noise limited. An ideal design would always be externally noise limited, but there are practical constraints in achieving this objective.

From Figure 7 it is clear that both 548-3 and 402-3 come close to the ideal, externally noise limited design, with the 548-3 better at frequencies below 3 MHz.

System Sensitivity

System sensitivity relates the signal strength (dBu) to the output SNR, while accounting for the antenna directivity and noise factor variations. The sensitivity for 632, 548-3 and 402-3 array is shown in Figure 8. In this example SNR is 10 dB and bandwidth is 125 Hz.

Figure 8 shows that both 548-3 and 402-3 are highly sensitive arrays, and both provide substantial improvement over 632 antenna at lower frequencies (f < 6MHz).

DF and SSL Capability

The 548-3 inward looking array is not suitable for either DF or DF with SSL.

Model 402-3 array can be used for both DF and SSL applications (requires optional DF and SSL processors), and provide very sensitive HF signal reception for both monitoring and DF purposes.

Installation Area Requirements

The 402-3 requires significantly less space than the array of full-band, high-gain log-periodic antennas, such as 548-3 outward looking array, with complete azimuth coverage

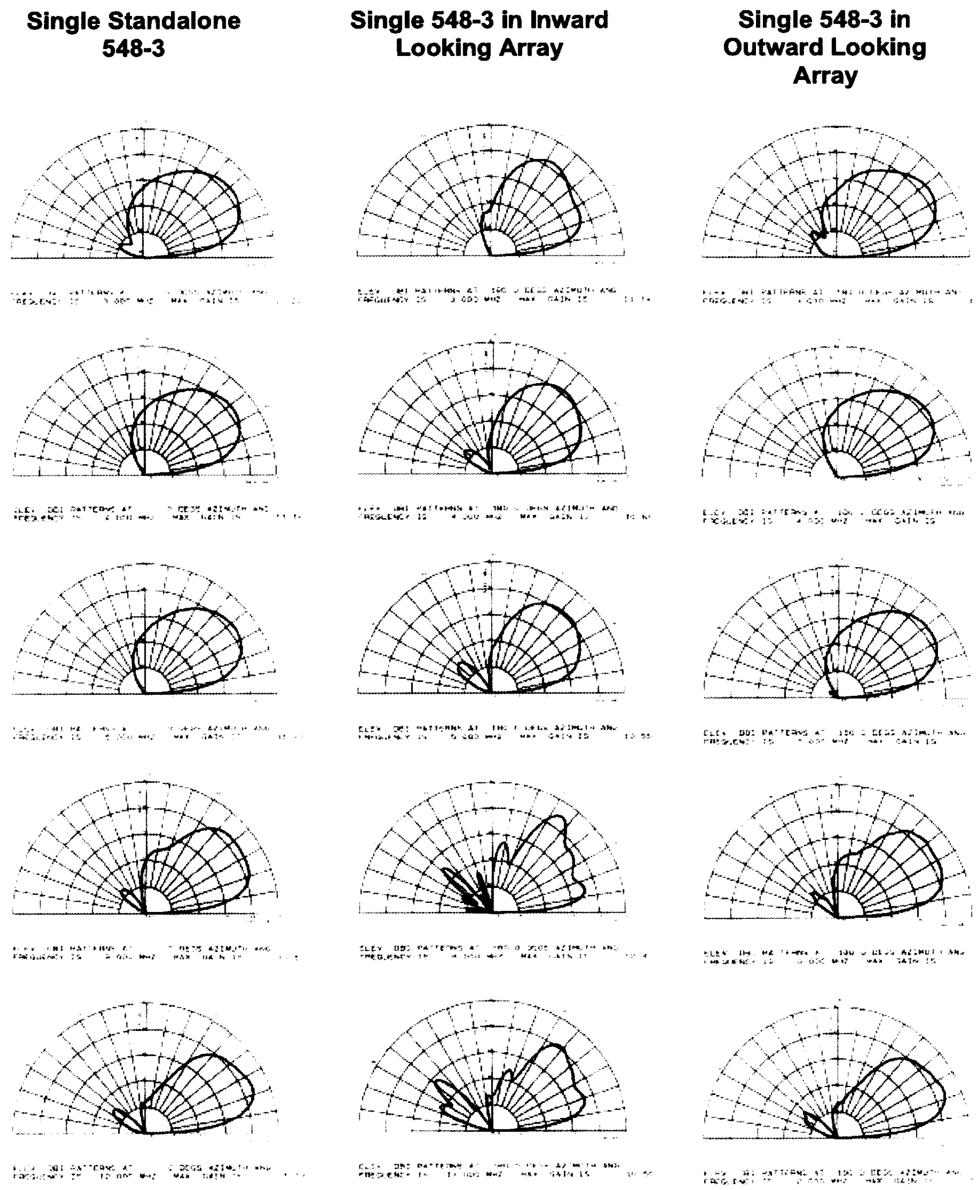

Single Standalone 548-3
Single 548-3 in Inward Looking Array
Single 548-3 in Outward Looking Array

Figure 1.

Single Standalone 548-3 | **Single 548-3 in Inward Looking Array** | **Single 548-3 in Outward Looking Array**

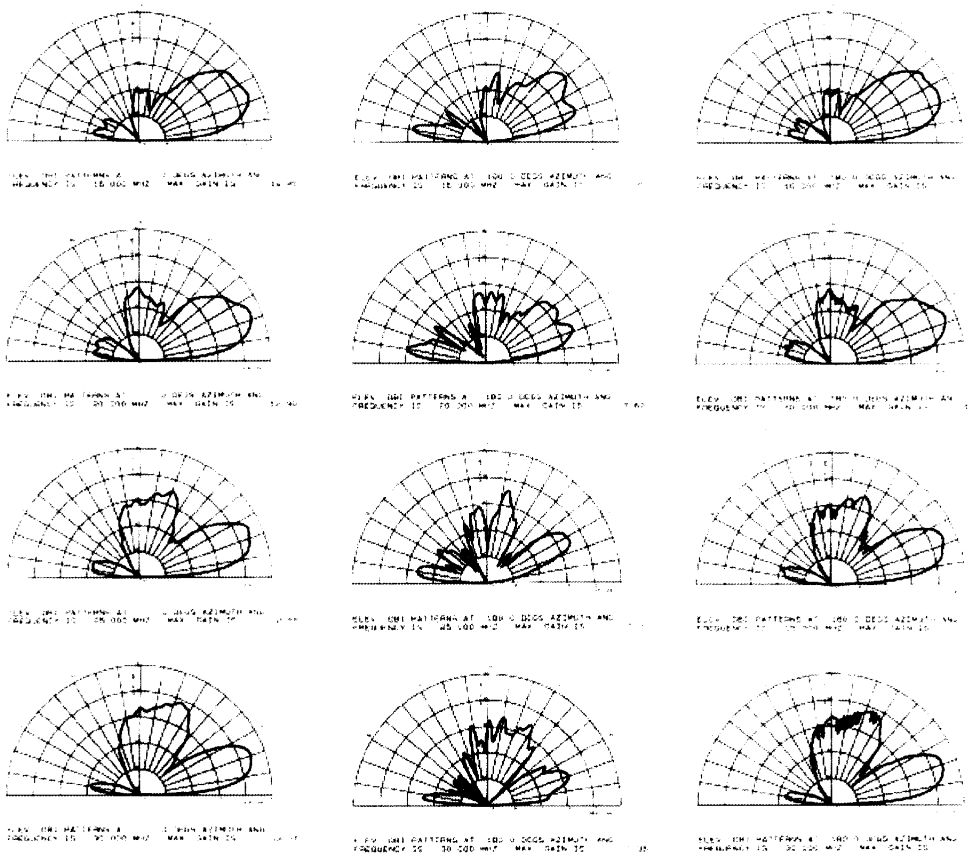
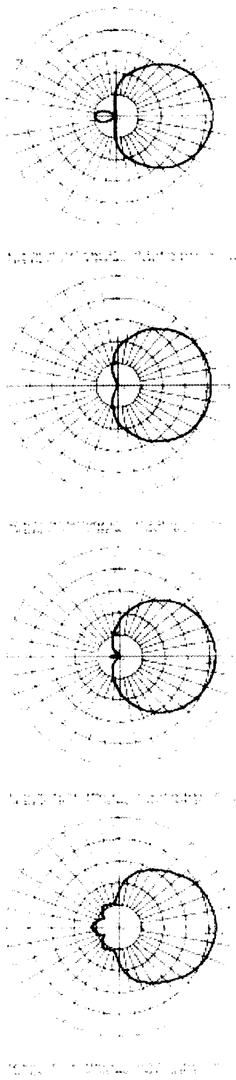


Figure 1. Continued

Figure 2. Azimuth Pattern of a Single 548-3 in 8 Element Outward Looking Array Configuration



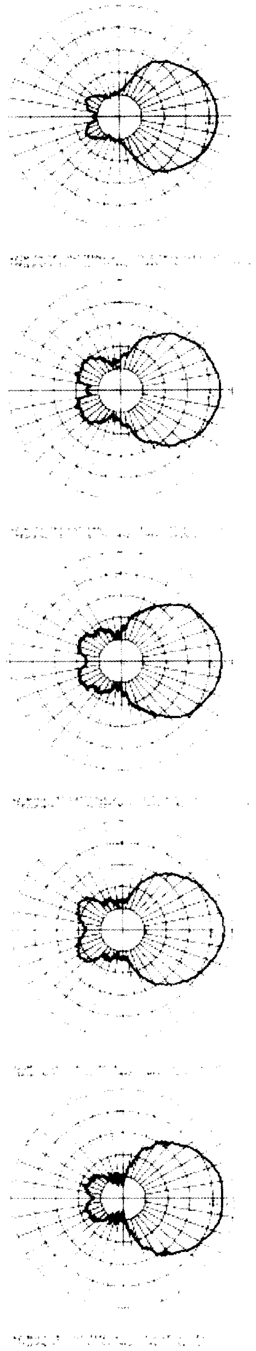
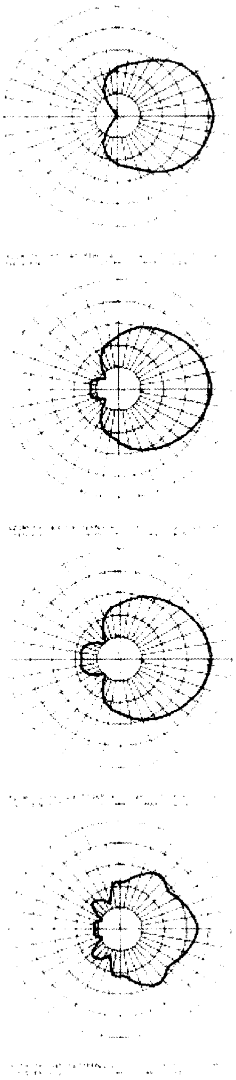


Figure 3. Azimuth Pattern of a Single 548-3 in 8 Element Inward Looking Array Configuration



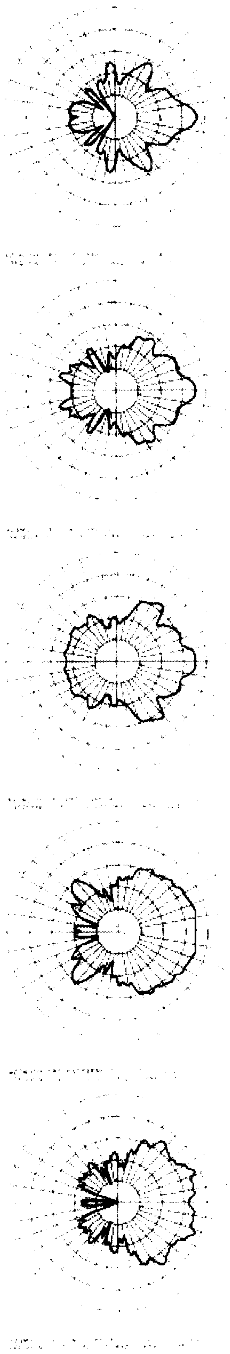


Figure 4. 402-3 Individual Element and Beam Elevation Patterns

Individual Element | **Beam**

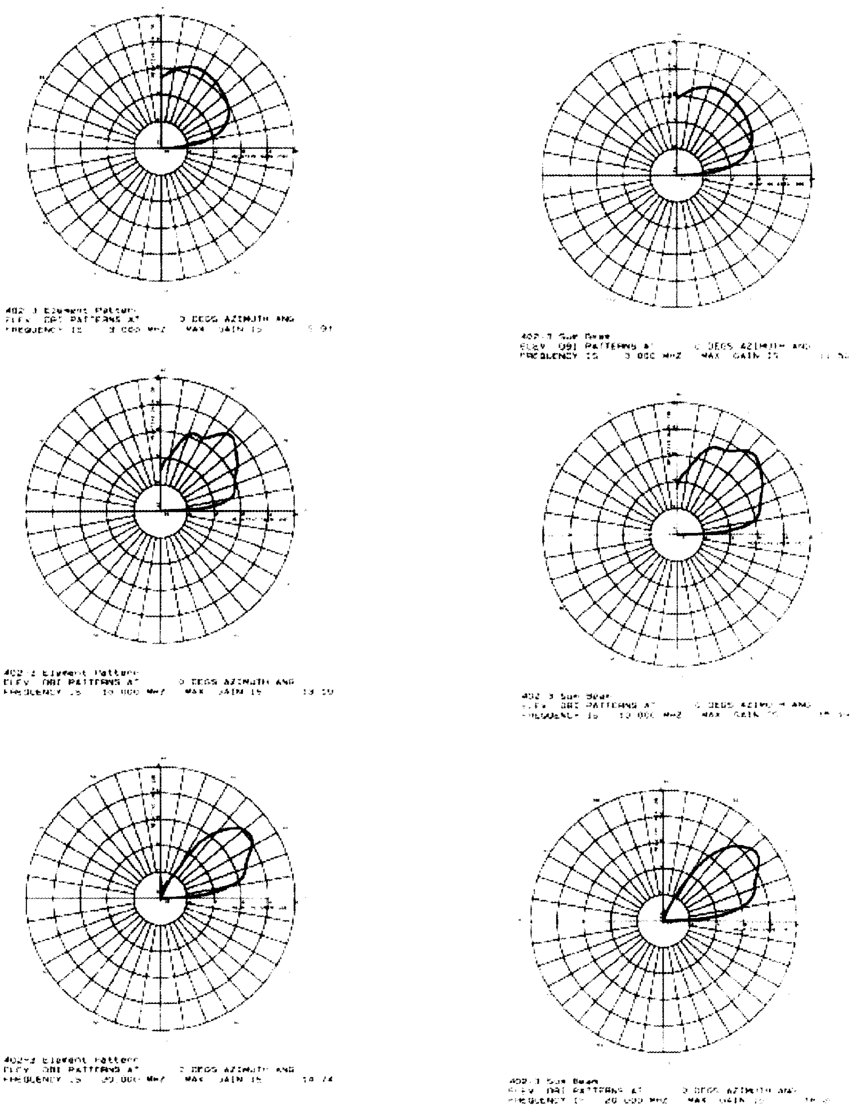


Figure 5. 402-3 Individual Element and Beam Azimuth Patterns

Individual Element | **Beam**

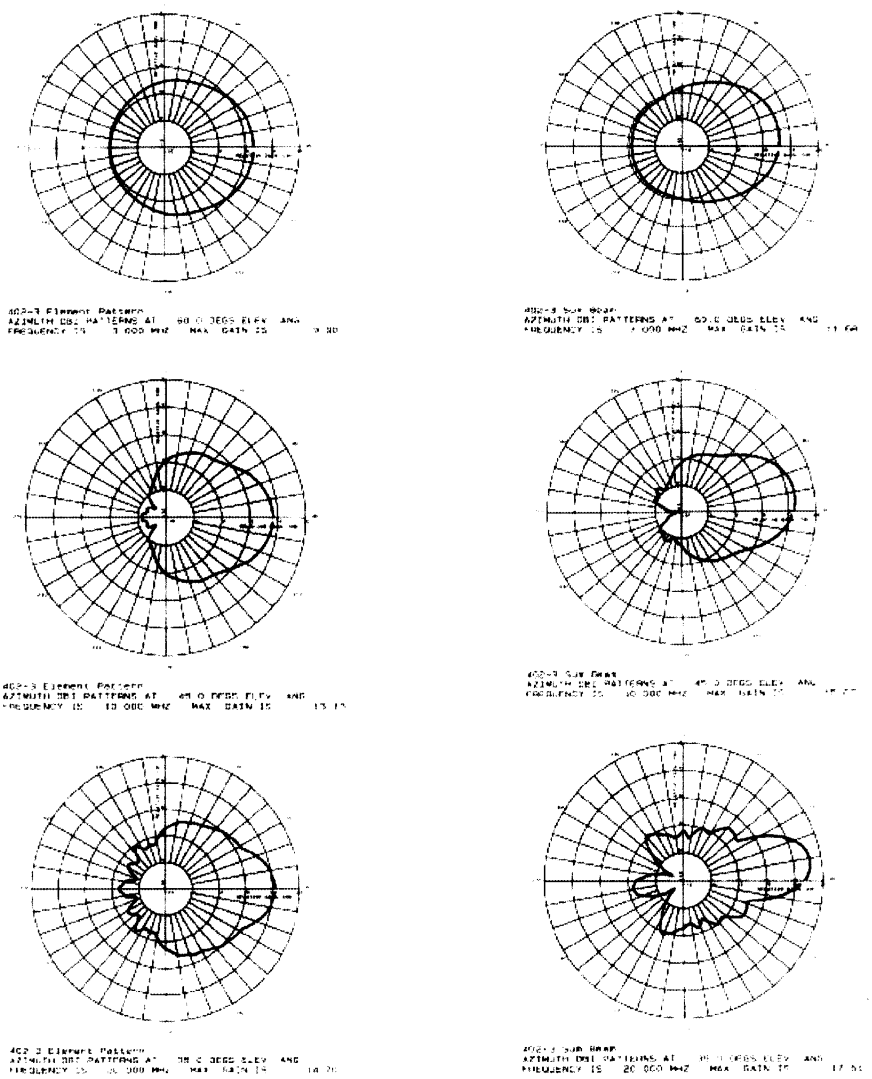


Figure 6. Elevation (Take-off) Angle Distribution as a Function of Transmitter Distance, Frequency and Time-of-Day

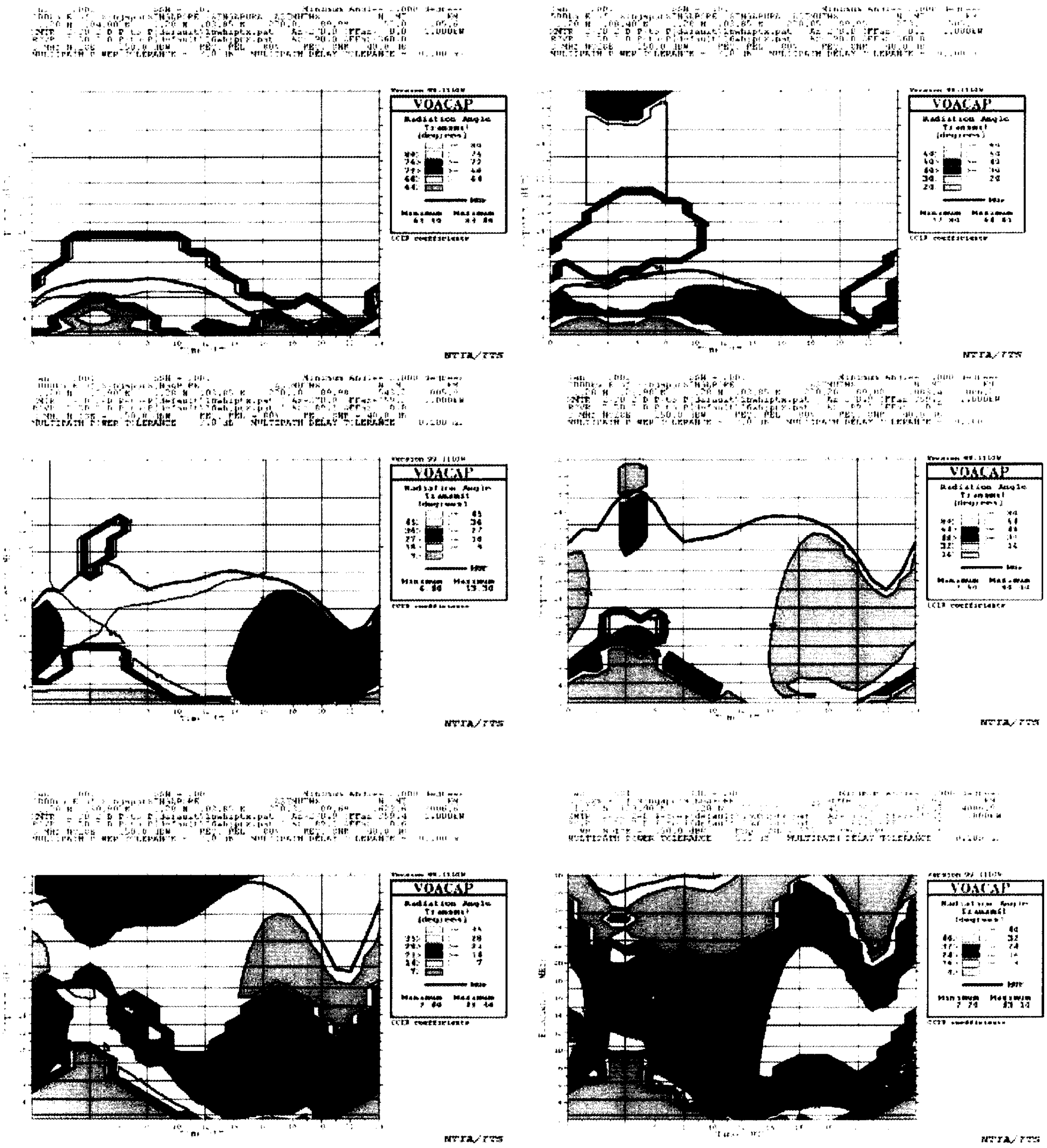


Figure 7. Atmospheric, Manmade Noise and Antenna Noise Factors vs. Frequency

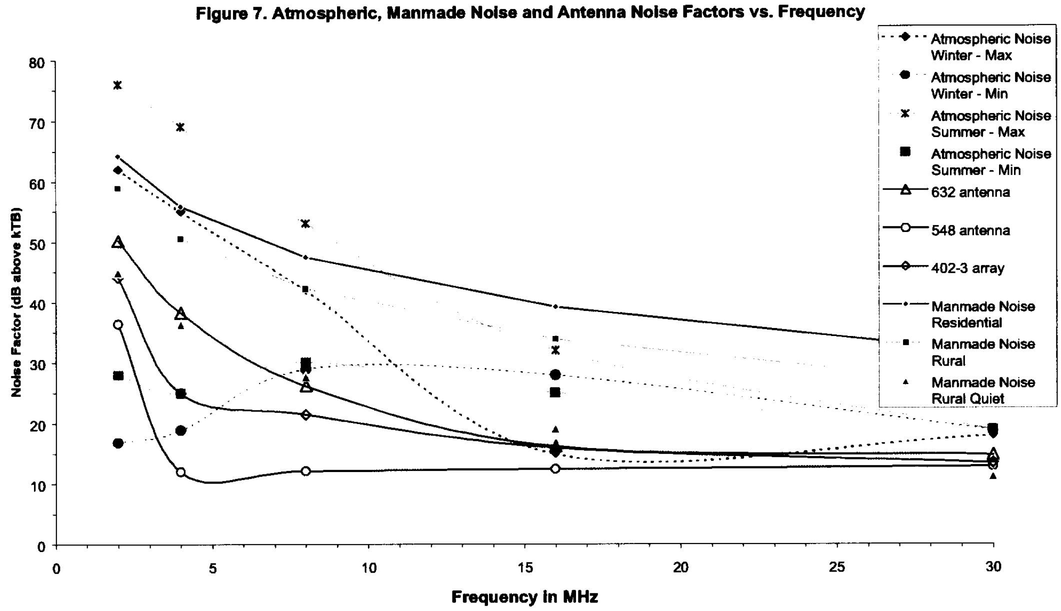
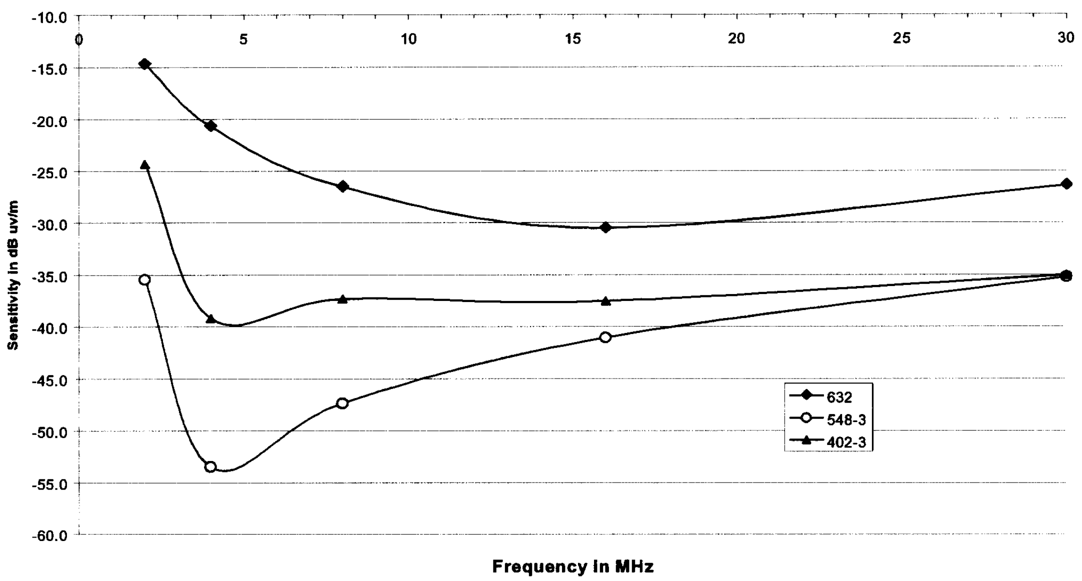


Figure 8. Sensitivity vs Frequency



RF Distribution, Cable, RF Switch and Receivers

The configuration of RF distribution, cable, RF switch and receiver components connected to the monitor antenna depends on many factors. TCI's proposal for these components is based on the following assumptions:

- Antenna site and monitoring site are 2 km apart
- There are N receivers connected to the antenna array, and it should be possible to connect all receivers to any of the available antenna outputs (10 outputs for 548-3 based solution, 22 outputs for 402-3 element based solution, 27 outputs for 402-3 beam solution)

The problem of significant distance between the antenna site and the monitoring site can be addressed either by:

a. Using long runs of coaxial cable (10, 22, or 27 cables) with possible use of preamplifiers (site survey will determine if preamplifier use is recommended)
b. Installing RF distribution, RF Switch and receiver at the antenna site and remoting both audio outputs and controls via fiber optics to the monitor site

The final solution for this problem will be recommended after the site survey, but for either solution the proposed RF distribution, RF switching and receivers will not change.

RF Distribution

The RF distribution has two components, primary and secondary RF distribution. The primary RF distribution provides splits all antenna outputs to provide all inputs to the secondary RF distribution that provides inputs to all RF switches. TCI proposal presents three alternatives based on three different antenna types:

- Outward looking 548-3 array (8 elements), 530-3 and 638-3 antennas (10 antenna outputs)
- 402-3 array (20 elements, 1 omni) and 638-3 antenna (22 antenna outputs)
- 402-3 array (20 beams, 5 elements, 1 omni) and 638-3 antenna (27 outputs)

RF Switch

For each of the antenna types TCI proposes non-blocking TCI Model 7184 RF switch with either 96 or 192 outputs (configured as four outputs per switch).

HF Receiver

TCI proposes either 96 or 192 TCI Model 8172/3 Receivers. The difference between TCI Model 8172 and TCI Model 8173 receiver is that Model 8173 has additional built-in digital pan-display output.

The pricing for these configurations is presented below. Note that the installation cost is an estimate. TCI recommends using local contactor for the installation works (with TCI's supervisor help). Also not included in the price is the cost of connecting the antenna site and monitor site (RF cable or fiber optics).

Pricing

The pricing information is presented for three system configurations (Items 1, 2 and 3):

- 548-3 antenna (Item 1.1)
- 402-3 antenna, elements (Item 2.1)
- 402-3 antenna, directive beams (Item 3.1)

For each of the antenna configuration there is a primary multicoupler with 192 RF outputs (Items 1.2, 2.2 and 3.2). Primary multicoupler is followed by either 96 or 192 output non-blocking switch. The outputs of the switch connect to either 96 or 192 HF receivers than can be either Model 8172 or Model 8173.

All of these combinations are listed in the following table. Note that for each antenna configuration:

- **a** line is for the configuration with 192 receiver channels (Model 8172 receiver)
- **b** line is for the configuration with 96 receiver channels (Model 8172 receiver)
- **c** line is for the configuration with 192 receiver channels (Model 8173 receiver)
- **d** line is for the configuration with 96 receiver channels (Model 8173 receiver)

	System Configuration			
	Ant	Primary Multicoupler	RF Switch	Rx
	1.1	1.2	1.3	1.4
a	8x548-3-02, 1x530-3-02, 1x638-2, total of ten outputs	10 RF Preamps, 2 8105 Multicoupler, 70 RF cables, 1 pre-wired rack	6 racks each containing: 2 8105 multicoupler, 8 7184 RF switch, 80 interconnect cables, 1 pre-wired rack	192 each 8172 receiver installed and cabled in 8 racks
b	8x548-3-02, 1x530-3-02, 1x638-2, total of ten outputs	10 RF Preamps, 2 8105 Multicoupler, 70 RF cables, 1 pre-wired rack	3 racks each containing: 2 8105 multicoupler, 8 7184 RF switch, 80 interconnect cables, 1 pre-wired rack	96 each 8172 receiver installed and cabled in 4 racks
c	8x548-3-02, 1x530-3-02, 1x638-2, total of ten outputs	10 RF Preamps, 2 8105 Multicoupler, 70 RF cables, 1 pre-wired rack	6 racks each containing: 2 8105 multicoupler, 8 7184 RF switch, 80 interconnect cables, 1 pre-wired rack	192 each 8173 receiver installed and cabled in 8 racks
d	8x548-3-02, 1x530-3-02, 1x638-2, total of ten outputs	10 RF Preamps, 2 8105 Multicoupler, 70 RF cables, 1 pre-wired rack	3 racks each containing: 2 8105 multicoupler, 8 7184 RF switch, 80 interconnect cables, 1 pre-wired rack	96 each 8173 receiver installed and cabled in 4 racks
	2.1	2.2	2.3	2.4
a	1x402-3, 1x638-2, total of twenty two outputs	22 RF Preamp, 4x8105 multicoupler, 1xHoriz.combiner, 154 cables, 1 pre-wired rack	6 racks each containing: 4 8105 multicoupler, 8 7184 RF switch, 176 interconnect cables, 1 pre-wired rack	192 each 8172 receiver installed and cabled in 8 racks
b	1x402-3, 1x638-2, total of twenty two outputs	22 RF Preamp, 4x8105 multicoupler, 1xHoriz.combiner, 154 cables, 1 pre-wired rack	3 racks each containing: 4 8105 multicoupler, 8 7184 RF switch, 176 interconnect cables, 1 pre-wired rack	96 each 8172 receiver installed and cabled in 4 racks
c	1x402-3, 1x638-2, total of twenty two outputs	22 RF Preamp, 4x8105 multicoupler, 1xHoriz.combiner, 154 cables, 1 pre-wired rack	6 racks each containing: 4 8105 multicoupler, 8 7184 RF switch, 176 interconnect cables, 1 pre-wired rack	192 each 8172 receiver installed and cabled in 8 racks
d	1x402-3, 1x638-2, total of twenty two outputs	22 RF Preamp, 4x8105 multicoupler, 1xHoriz.combiner, 154 cables, 1 pre-wired rack	3 racks each containing: 4 8105 multicoupler, 8 7184 RF switch, 176 interconnect cables, 1 pre-wired rack	96 each 8172 receiver installed and cabled in 4 racks

	3.1	3.2	3.3	3.4
a	1x402-3, 1x638-2, total of twenty seven outputs	27 RF Preamps, 7 8105 multicoupler, 3 8507 Beamformer unit, 1 Horiz combiner, RF cables, 2 pre-wired racks	6 racks each containing: 4 8105 multicoupler, 8 7184 RF switch, 216 interconnect cables, 1 pre-wired rack	192 each 8172 receiver installed and cabled in 8 racks
b	1x402-3, 1x638-2, total of twenty seven outputs	27 RF Preamps, 7 8105 multicoupler, 3 8507 Beamformer unit, 1 Horiz combiner, RF cables, 2 pre-wired racks	3 racks each containing: 4 8105 multicoupler, 8 7184 RF switch, 216 interconnect cables, 1 pre-wired rack	96 each 8172 receiver installed and cabled in 4 racks
c	1x402-3, 1x638-2, total of twenty seven outputs	27 RF Preamps, 7 8105 multicoupler, 3 8507 Beamformer unit, 1 Horiz combiner, RF cables, 2 pre-wired racks	6 racks each containing: 4 8105 multicoupler, 8 7184 RF switch, 216 interconnect cables, 1 pre-wired rack	192 each 8172 receiver installed and cabled in 8 racks
d	1x402-3, 1x638-2, total of twenty seven outputs	27 RF Preamps, 7 8105 multicoupler, 3 8507 Beamformer unit, 1 Horiz combiner, RF cables, 2 pre-wired racks	3 racks each containing: 4 8105 multicoupler, 8 7184 RF switch, 216 interconnect cables, 1 pre-wired rack	96 each 8172 receiver installed and cabled in 4 racks

Pricing Matrix

System Configurations	Antennas	Ant. Install Estimate	Primary RFD	RF Switch	Receivers	
1	1.1		1.2	1.3	1.4	Total
a	$264,076	$200,000	$43,050	$415,800	$747,600	$1,670,526
b	$264,076	$200,000	$43,050	$220,500	$407,400	$1,135,026
c	$264,076	$200,000	$43,050	$415,800	$848,400	$1,771,326
d	$264,076	$200,000	$43,050	$220,500	$457,800	$1,185,426
2	2.1		2.2	2.3	2.4	Total
a	$1,275,750	$450,000	$94,500	$737,100	$747,600	$3,304,950
b	$1,275,750	$450,000	$94,500	$384,300	$407,400	$2,611,950
c	$1,275,750	$450,000	$94,500	$737,100	$848,400	$3,405,750
d	$1,275,750	$450,000	$94,500	$384,300	$457,800	$2,662,350
3	3.1		3.2	3.3	3.4	Total
a	$1,275,750	$450,000	$185,850	$793,800	$747,600	$3,453,000
b	$1,275,750	$450,000	$185,850	$409,500	$407,400	$2,728,500
c	$1,275,750	$450,000	$185,850	$793,800	$848,400	$3,553,800
d	$1,275,750	$450,000	$185,850	$409,500	$457,800	$2,778,900

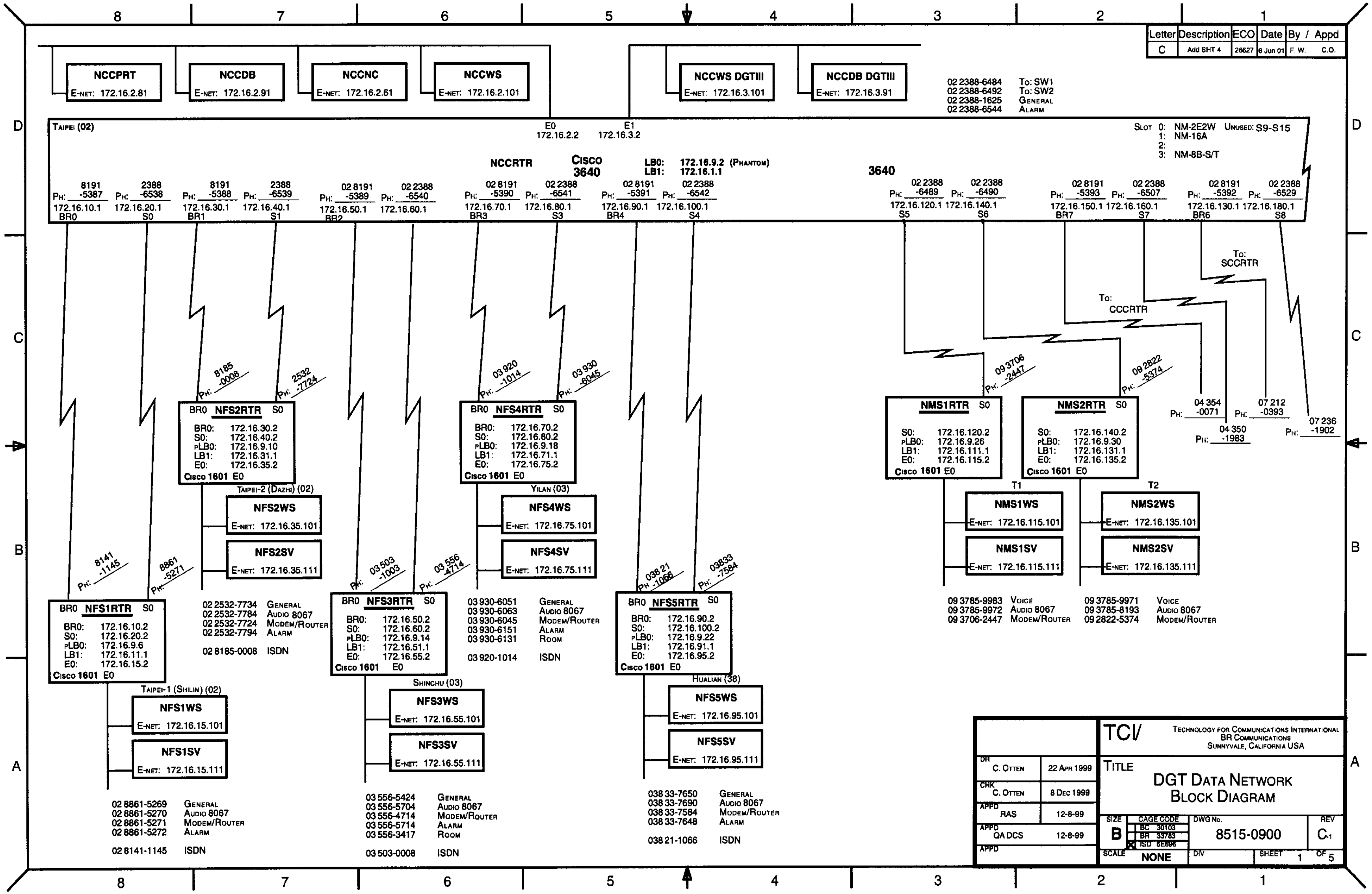
Summary

TCI proposal present two antenna alternatives for the HFRS, one based on 548-3 antenna array and one based on 402-3 array (elements or directive beams).

Both solutions provide superior signal monitoring capability, with the 402-3 providing the room for expansion in both monitoring (use of beams) and DF and SSL applications.

If 548-3 antenna array is selected, it will provide significant improvement in sensitivity at low frequencies (<6 MHz) compared to the 632 antenna, which is currently used for the DF application. It will also provide additional signal selectivity based on antenna directive patterns. This antenna also requires a separate horizontally polarized omnidirectional antenna, which significantly increases land area required for installation.

If 402-3 antenna array is selected, although it is slightly less sensitive than 548-3, it will also provide significant improvement in sensitivity at low frequencies (<6 MHz) compared to the 632 antenna. Additionally, 402-3 array can be configured for monitoring to use directive beams, and it can be also used as a DF antenna compatible with SSL measurements.



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NCCDB
E-net: 172.16.2.91
NCCNC
E-net: 172.16.2.61
NCCWS
E-net: 172.16.2.101
NCCWS DGTIII
E-net: 172.16.3.101
NCCDB DGTIII
E-net: 172.16.3.91
02 2388-6484 To: SW1
02 2388-6492 To: SW2
02 2388-1625 General
02 2388-6544 Alarm
Taipei (02)
E0 172.16.2.2
E1 172.16.3.2
NCCRTR
Cisco 3640
LB0: 172.16.9.2 (Phantom)
LB1: 172.16.1.1
3640
Slot 0: NM-2E2W Unused: S9-S15
1: NM-16A
2:
3: NM-8B-S/T
8191 Ph: -5387 172.16.10.1 BR0
2388 Ph: -6538 172.16.20.1 S0
8191 Ph: -5388 172.16.30.1 BR1
2388 Ph: -6539 172.16.40.1 S1
02 8191 Ph: -5389 172.16.50.1 BR2
02 2388 Ph: -6540 172.16.60.1
02 8191 Ph: -5390 172.16.70.1 BR3
02 2388 Ph: -6541 172.16.80.1 S3
02 8191 Ph: -5391 172.16.90.1 BR4
02 2388 Ph: -6542 172.16.100.1 S4
02 2388 Ph: -6489 172.16.120.1 S5
02 2388 Ph: -6490 172.16.140.1 S6
02 8191 Ph: -5393 172.16.150.1 BR7
02 2388 Ph: -6507 172.16.160.1 S7
02 8191 Ph: -5392 172.16.130.1 BR6
02 2388 Ph: -6529 172.16.180.1 S8
To: SCCRTR
To: CCCRTR
8141 Ph: -1145
8861 Ph: -5271
BR0 NFS1RTR S0
BR0: 172.16.10.2
S0: 172.16.20.2
pLB0: 172.16.9.6
LB1: 172.16.11.1
E0: 172.16.15.2
Cisco 1601 E0
Taipei-1 (Shilin) (02)
NFS1WS
E-net: 172.16.15.101
NFS1SV
E-net: 172.16.15.111
02 8861-5269 General
02 8861-5270 Audio 8067
02 8861-5271 Modem/Router
02 8861-5272 Alarm
02 8141-1145 ISDN
8185 Ph: -0008
2532 Ph: -7724
BR0 NFS2RTR S0
BR0: 172.16.30.2
S0: 172.16.40.2
pLB0: 172.16.9.10
LB1: 172.16.31.1
E0: 172.16.35.2
Cisco 1601 E0
Taipei-2 (Dazhi) (02)
NFS2WS
E-net: 172.16.35.101
NFS2SV
E-net: 172.16.35.111
02 2532-7734 General
02 2532-7784 Audio 8067
02 2532-7724 Modem/Router
02 2532-7794 Alarm
02 8185-0008 ISDN
03 503 Ph: -1003
03 556 Ph: -4714
BR0 NFS3RTR S0
BR0: 172.16.50.2
S0: 172.16.60.2
pLB0: 172.16.9.14
LB1: 172.16.51.1
E0: 172.16.55.2
Cisco 1601 E0
Shinchu (03)
NFS3WS
E-net: 172.16.55.101
NFS3SV
E-net: 172.16.55.111
03 556-5424 General
03 556-5704 Audio 8067
03 556-4714 Modem/Router
03 556-5714 Alarm
03 556-3417 Room
03 503-0008 ISDN
03 920 Ph: -1014
03 930 Ph: -6045
BR0 NFS4RTR S0
BR0: 172.16.70.2
S0: 172.16.80.2
pLB0: 172.16.9.18
LB1: 172.16.71.1
E0: 172.16.75.2
Cisco 1601 E0
Yilan (03)
NFS4WS
E-net: 172.16.75.101
NFS4SV
E-net: 172.16.75.111
03 930-6051 General
03 930-6063 Audio 8067
03 930-6045 Modem/Router
03 930-6151 Alarm
03 930-6131 Room
03 920-1014 ISDN
038 21 Ph: -1066
03833 Ph: -7584
BR0 NFS5RTR S0
BR0: 172.16.90.2
S0: 172.16.100.2
pLB0: 172.16.9.22
LB1: 172.16.91.1
E0: 172.16.95.2
Cisco 1601 E0
Hualian (38)
NFS5WS
E-net: 172.16.95.101
NFS5SV
E-net: 172.16.95.111
038 33-7650 General
038 33-7690 Audio 8067
038 33-7584 Modem/Router
038 33-7648 Alarm
038 21-1066 ISDN
09 3706 Ph: -2447
09 2822 Ph: -5374
NMS1RTR S0
S0: 172.16.120.2
pLB0: 172.16.9.26
LB1: 172.16.111.1
E0: 172.16.115.2
Cisco 1601 E0
T1
NMS1WS
E-net: 172.16.115.101
NMS1SV
E-net: 172.16.115.111
09 3785-9983 Voice
09 3785-9972 Audio 8067
09 3706-2447 Modem/Router
NMS2RTR S0
S0: 172.16.140.2
pLB0: 172.16.9.30
LB1: 172.16.131.1
E0: 172.16.135.2
Cisco 1601 E0
T2
NMS2WS
E-net: 172.16.135.101
NMS2SV
E-net: 172.16.135.111
09 3785-9971 Voice
09 3785-8193 Audio 8067
09 2822-5374 Modem/Router
04 354 Ph: -0071
04 350 Ph: -1983
07 212 Ph: -0393
07 236 Ph: -1902
TCI/
Technology for Communications International
BR Communications
Sunnyvale, California USA
DR C. Otten 22 Apr 1999
CHK C. Otten 8 Dec 1999
APPD RAS 12-8-99
APPD QA DCS 12-8-99
APPD
Title
DGT Data Network
Block Diagram
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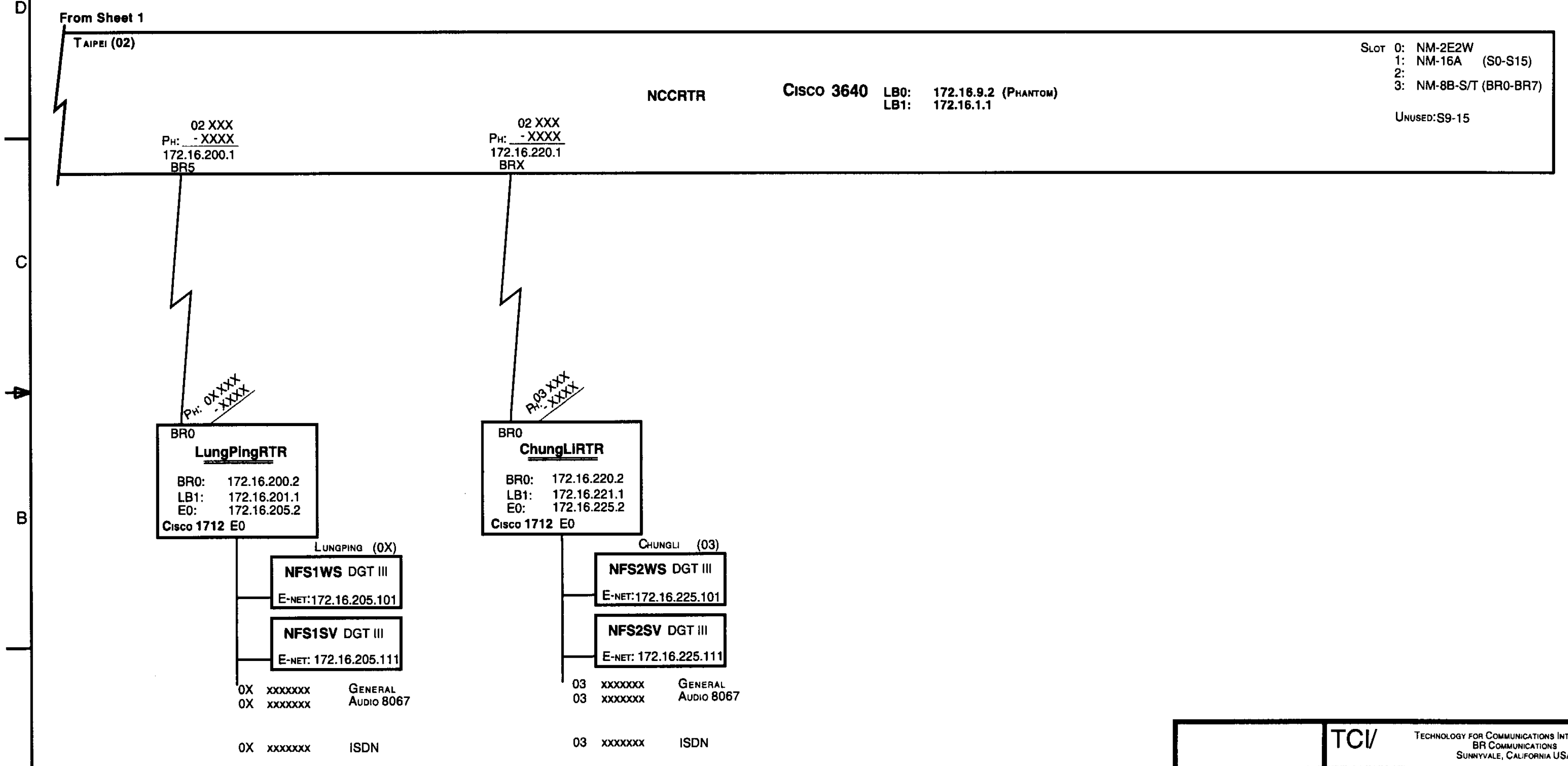
DWG No. 8515-0900
Rev C1
Scale NONE
Div
Sheet 1 of 5



DR	C. Otten	22 Apr 2001
CHK		
APPD		
APPD		
APPD		

TCI/ Technology for Communications International, BR Communications, Sunnyvale, California USA

TITLE: DGT Data Network Block Diagram

SIZE	CAGE CODE	DWG No.	REV
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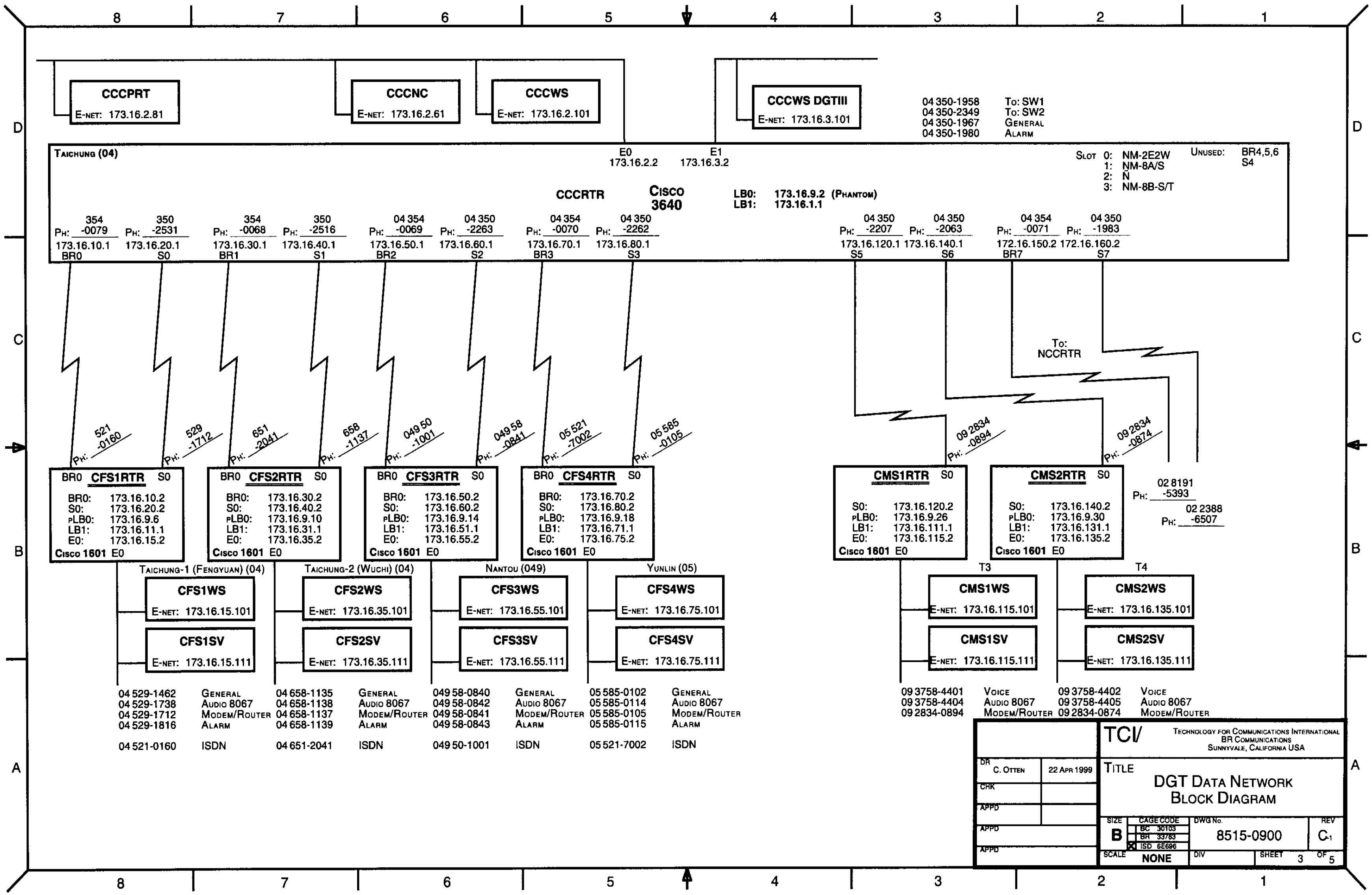
SCALE NONE		DIV	SHEET 2 OF 5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E-net: 173.16.2.81
CCCNC
E-net: 173.16.2.61
CCCWS
E-net: 173.16.2.101
CCCWS DGTIII
E-net: 173.16.3.101
04 350-1958 To: SW1
04 350-2349 To: SW2
04 350-1967 General
04 350-1980 Alarm
Taichung (04)
E0 173.16.2.2
E1 173.16.3.2
CCCRTR
Cisco 3640
LB0: 173.16.9.2 (Phantom)
LB1: 173.16.1.1
Slot 0: NM-2E2W
1: NM-8A/S
2: N
3: NM-8B-S/T
Unused: BR4,5,6 S4
354 Ph: -0079 173.16.10.1 BR0
350 Ph: -2531 173.16.20.1 S0
354 Ph: -0068 173.16.30.1 BR1
350 Ph: -2516 173.16.40.1 S1
04 354 Ph: -0069 173.16.50.1 BR2
04 350 Ph: -2263 173.16.60.1 S2
04 354 Ph: -0070 173.16.70.1 BR3
04 350 Ph: -2262 173.16.80.1 S3
04 350 Ph: -2207 173.16.120.1 S5
04 350 Ph: -2063 173.16.140.1 S6
04 354 Ph: -0071 172.16.150.2 BR7
04 350 Ph: -1983 172.16.160.2 S7
To: NCCRTR
521 Ph: -0160
529 Ph: -1712
651 Ph: -2041
658 Ph: -1137
049 50 Ph: -1001
049 58 Ph: -0841
05 521 Ph: -7002
05 585 Ph: -0105
09 2834 Ph: -0894
09 2834 Ph: -0874
02 8191 Ph: -5393
02 2388 Ph: -6507
BR0 CFS1RTR S0
BR0: 173.16.10.2
S0: 173.16.20.2
pLB0: 173.16.9.6
LB1: 173.16.11.1
E0: 173.16.15.2
Cisco 1601 E0
BR0 CFS2RTR S0
BR0: 173.16.30.2
S0: 173.16.40.2
pLB0: 173.16.9.10
LB1: 173.16.31.1
E0: 173.16.35.2
Cisco 1601 E0
BR0 CFS3RTR S0
BR0: 173.16.50.2
S0: 173.16.60.2
pLB0: 173.16.9.14
LB1: 173.16.51.1
E0: 173.16.55.2
Cisco 1601 E0
BR0 CFS4RTR S0
BR0: 173.16.70.2
S0: 173.16.80.2
pLB0: 173.16.9.18
LB1: 173.16.71.1
E0: 173.16.75.2
Cisco 1601 E0
CMS1RTR S0
S0: 173.16.120.2
pLB0: 173.16.9.26
LB1: 173.16.111.1
E0: 173.16.115.2
Cisco 1601 E0
CMS2RTR S0
S0: 173.16.140.2
pLB0: 173.16.9.30
LB1: 173.16.131.1
E0: 173.16.135.2
Cisco 1601 E0
Taichung-1 (Fengyuan) (04)
Taichung-2 (Wuchi) (04)
Nantou (049)
Yunlin (05)
T3
T4
CFS1WS E-net: 173.16.15.101
CFS1SV E-net: 173.16.15.111
CFS2WS E-net: 173.16.35.101
CFS2SV E-net: 173.16.35.111
CFS3WS E-net: 173.16.55.101
CFS3SV E-net: 173.16.55.111
CFS4WS E-net: 173.16.75.101
CFS4SV E-net: 173.16.75.111
CMS1WS E-net: 173.16.115.101
CMS1SV E-net: 173.16.115.111
CMS2WS E-net: 173.16.135.101
CMS2SV E-net: 173.16.135.111
04 529-1462 General
04 529-1738 Audio 8067
04 529-1712 Modem/Router
04 529-1816 Alarm
04 521-0160 ISDN
04 658-1135 General
04 658-1138 Audio 8067
04 658-1137 Modem/Router
04 658-1139 Alarm
04 651-2041 ISDN
049 58-0840 General
049 58-0842 Audio 8067
049 58-0841 Modem/Router
049 58-0843 Alarm
049 50-1001 ISDN
05 585-0102 General
05 585-0114 Audio 8067
05 585-0105 Modem/Router
05 585-0115 Alarm
05 521-7002 ISDN
09 3758-4401 Voice
09 3758-4404 Audio 8067
09 2834-0894 Modem/Router
09 3758-4402 Voice
09 3758-4405 Audio 8067
09 2834-0874 Modem/Router
TCI/
Technology for Communications International
BR Communications
Sunnyvale, California USA
DR C. Otten 22 Apr 1999
CHK
APPD
APPD
APPD
Title
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Rev C1
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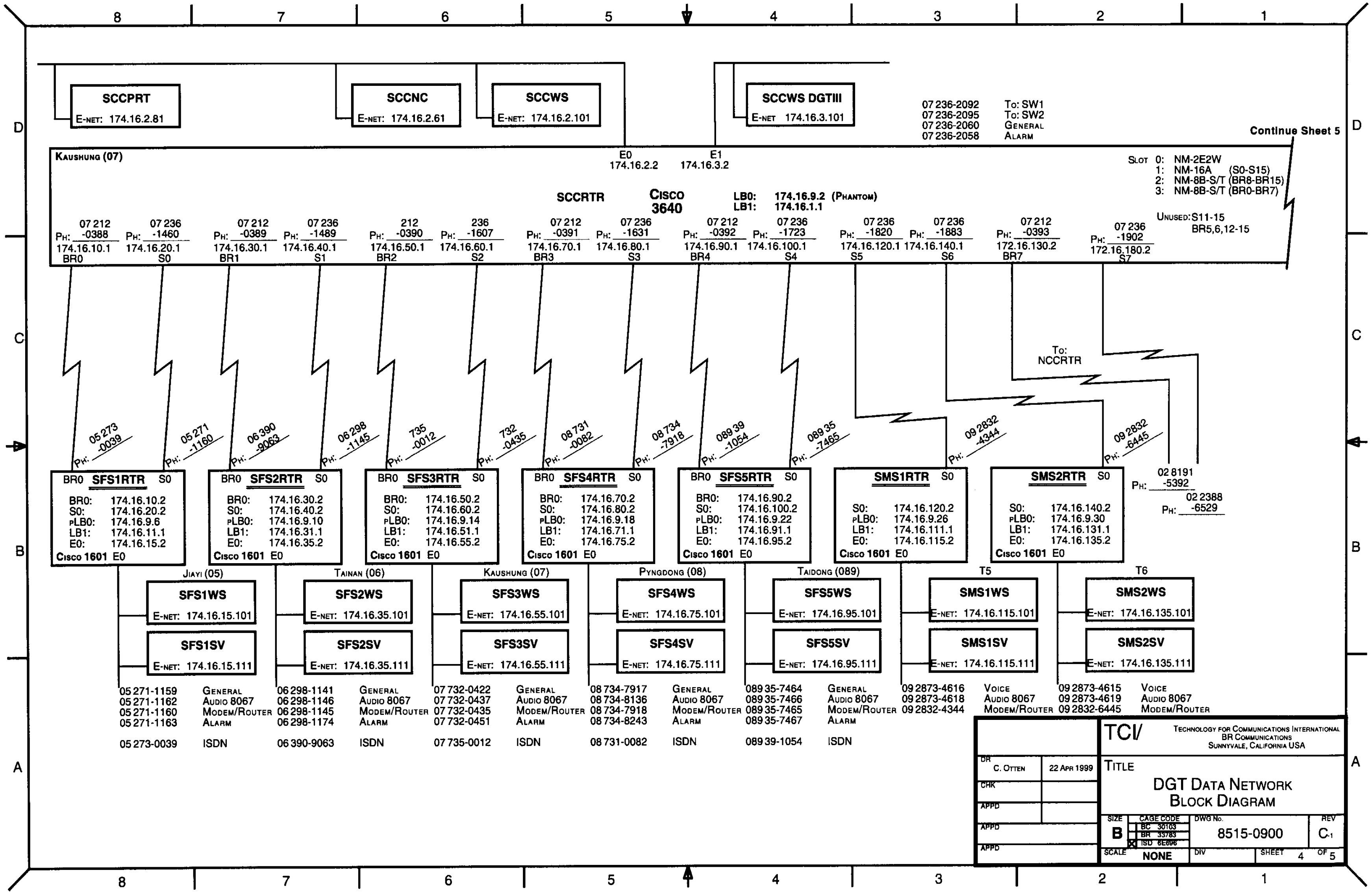

SCCPRT
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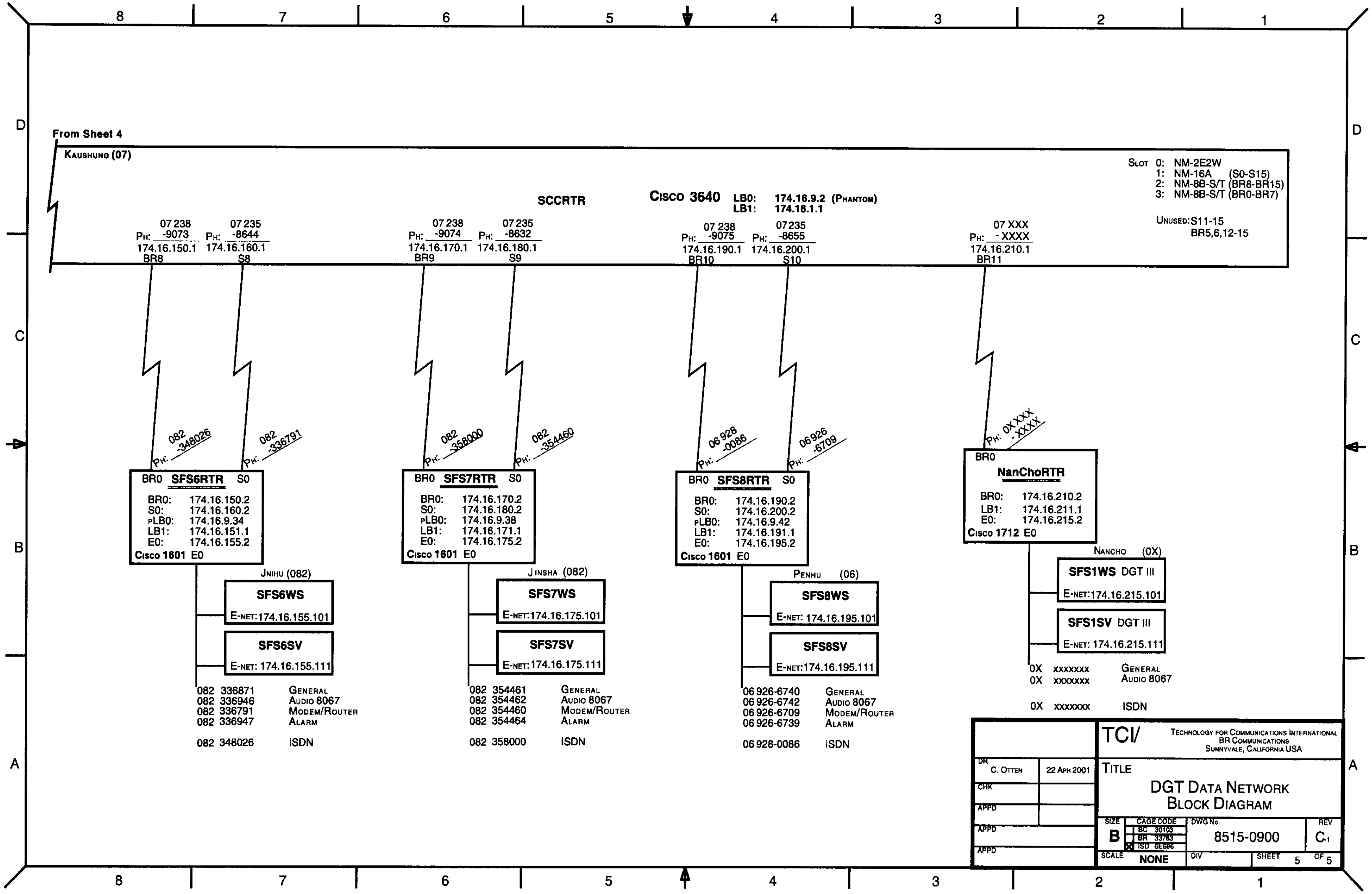
SCCNC
E-NET: 174.16.2.61
SCCWS
E-NET: 174.16.2.101
SCCWS DGTIII
E-NET 174.16.3.101
07 236-2092 To: SW1
07 236-2095 To: SW2
07 236-2060 General
07 236-2058 Alarm
Continue Sheet 5
Kaushung (07)
E0 174.16.2.2
E1 174.16.3.2
SCCRTR
Cisco 3640
LB0: 174.16.9.2 (Phantom)
LB1: 174.16.1.1
Slot 0: NM-2E2W
1: NM-16A (S0-S15)
2: NM-8B-S/T (BR8-BR15)
3: NM-8B-S/T (BR0-BR7)
Unused: S11-15
BR5,6,12-15
07 212 Ph: -0388 174.16.10.1 BR0
07 236 Ph: -1460 174.16.20.1 S0
07 212 Ph: -0389 174.16.30.1 BR1
07 236 Ph: -1489 174.16.40.1 S1
212 Ph: -0390 174.16.50.1 BR2
236 Ph: -1607 174.16.60.1 S2
07 212 Ph: -0391 174.16.70.1 BR3
07 236 Ph: -1631 174.16.80.1 S3
07 212 Ph: -0392 174.16.90.1 BR4
07 236 Ph: -1723 174.16.100.1 S4
07 236 Ph: -1820 174.16.120.1 S5
07 236 Ph: -1883 174.16.140.1 S6
07 212 Ph: -0393 172.16.130.2 BR7
07 236 Ph: -1902 172.16.180.2 S7
To: NCCRTR
Ph: 05 273 -0039
Ph: 05 271 -1160
Ph: 06 390 -9063
Ph: 06 298 -1145
Ph: 735 -0012
Ph: 732 -0435
Ph: 08 731 -0082
Ph: 08 734 -7918
Ph: 089 39 -1054
Ph: 089 35 -7465
Ph: 09 2832 -4344
Ph: 09 2832 -6445
02 8191 Ph: -5392
02 2388 Ph: -6529
BR0 SFS1RTR S0
BR0: 174.16.10.2
S0: 174.16.20.2
pLB0: 174.16.9.6
LB1: 174.16.11.1
E0: 174.16.15.2
Cisco 1601 E0
BR0 SFS2RTR S0
BR0: 174.16.30.2
S0: 174.16.40.2
pLB0: 174.16.9.10
LB1: 174.16.31.1
E0: 174.16.35.2
Cisco 1601 E0
BR0 SFS3RTR S0
BR0: 174.16.50.2
S0: 174.16.60.2
pLB0: 174.16.9.14
LB1: 174.16.51.1
E0: 174.16.55.2
Cisco 1601 E0
BR0 SFS4RTR S0
BR0: 174.16.70.2
S0: 174.16.80.2
pLB0: 174.16.9.18
LB1: 174.16.71.1
E0: 174.16.75.2
Cisco 1601 E0
BR0 SFS5RTR S0
BR0: 174.16.90.2
S0: 174.16.100.2
pLB0: 174.16.9.22
LB1: 174.16.91.1
E0: 174.16.95.2
Cisco 1601 E0
SMS1RTR S0
S0: 174.16.120.2
pLB0: 174.16.9.26
LB1: 174.16.111.1
E0: 174.16.115.2
Cisco 1601 E0
SMS2RTR S0
S0: 174.16.140.2
pLB0: 174.16.9.30
LB1: 174.16.131.1
E0: 174.16.135.2
Cisco 1601 E0
Jiayi (05)
Tainan (06)
Kaushung (07)
Pyngdong (08)
Taidong (089)
T5
T6
SFS1WS E-NET: 174.16.15.101
SFS1SV E-NET: 174.16.15.111
SFS2WS E-NET: 174.16.35.101
SFS2SV E-NET: 174.16.35.111
SFS3WS E-NET: 174.16.55.101
SFS3SV E-NET: 174.16.55.111
SFS4WS E-NET: 174.16.75.101
SFS4SV E-NET: 174.16.75.111
SFS5WS E-NET: 174.16.95.101
SFS5SV E-NET: 174.16.95.111
SMS1WS E-NET: 174.16.115.101
SMS1SV E-NET: 174.16.115.111
SMS2WS E-NET: 174.16.135.101
SMS2SV E-NET: 174.16.135.111
05 271-1159 General
05 271-1162 Audio 8067
05 271-1160 Modem/Router
05 271-1163 Alarm
05 273-0039 ISDN
06 298-1141 General
06 298-1146 Audio 8067
06 298-1145 Modem/Router
06 298-1174 Alarm
06 390-9063 ISDN
07 732-0422 General
07 732-0437 Audio 8067
07 732-0435 Modem/Router
07 732-0451 Alarm
07 735-0012 ISDN
08 734-7917 General
08 734-8136 Audio 8067
08 734-7918 Modem/Router
08 734-8243 Alarm
08 731-0082 ISDN
089 35-7464 General
089 35-7466 Audio 8067
089 35-7465 Modem/Router
089 35-7467 Alarm
089 39-1054 ISDN
09 2873-4616 Voice
09 2873-4618 Audio 8067
09 2832-4344 Modem/Router
09 2873-4615 Voice
09 2873-4619 Audio 8067
09 2832-6445 Modem/Router
TCI/ Technology for Communications International
BR Communications
Sunnyvale, California USA
DR C. Otten 22 Apr 1999
CHK
APPD
APPD
APPD
Title
DGT Data Network
Block Diagram
Size B
Cage Code BC 30103 BR 33783 ISD 6E696
DWG No. 8515-0900
Rev C1
Scale NONE
DIV
Sheet 4 of 5


From Sheet 4
Kaushung (07)
SCCRTR
Cisco 3640 LB0: 174.16.9.2 (Phantom)
LB1: 174.16.1.1
Slot 0: NM-2E2W
1: NM-16A (S0-S15)
2: NM-8B-S/T (BR8-BR15)
3: NM-8B-S/T (BR0-BR7)
Unused: S11-15
BR5,6,12-15
07 238 Ph: -9073 174.16.150.1 BR8
07 235 Ph: -8644 174.16.160.1 S8
07 238 Ph: -9074 174.16.170.1 BR9
07 235 Ph: -8632 174.16.180.1 S9
07 238 Ph: -9075 174.16.190.1 BR10
07 235 Ph: -8655 174.16.200.1 S10
07 XXX Ph: - XXXX 174.16.210.1 BR11
Ph: 082 -348026
Ph: 082 -336791
BR0 SFS6RTR S0
BR0: 174.16.150.2
S0: 174.16.160.2
pLB0: 174.16.9.34
LB1: 174.16.151.1
E0: 174.16.155.2
Cisco 1601 E0
Jnihu (082)
SFS6WS
E-net: 174.16.155.101
SFS6SV
E-net: 174.16.155.111
082 336871 General
082 336946 Audio 8067
082 336791 Modem/Router
082 336947 Alarm
082 348026 ISDN
Ph: 082 -358000
Ph: 082 -354460
BR0 SFS7RTR S0
BR0: 174.16.170.2
S0: 174.16.180.2
pLB0: 174.16.9.38
LB1: 174.16.171.1
E0: 174.16.175.2
Cisco 1601 E0
Jinsha (082)
SFS7WS
E-net: 174.16.175.101
SFS7SV
E-net: 174.16.175.111
082 354461 General
082 354462 Audio 8067
082 354460 Modem/Router
082 354464 Alarm
082 358000 ISDN
Ph: 06 928 -0086
Ph: 06 926 -6709
BR0 SFS8RTR S0
BR0: 174.16.190.2
S0: 174.16.200.2
pLB0: 174.16.9.42
LB1: 174.16.191.1
E0: 174.16.195.2
Cisco 1601 E0
Penhu (06)
SFS8WS
E-net: 174.16.195.101
SFS8SV
E-net: 174.16.195.111
06 926-6740 General
06 926-6742 Audio 8067
06 926-6709 Modem/Router
06 926-6739 Alarm
06 928-0086 ISDN
Ph: 0X XXX -XXXX
BR0
NanChoRTR
BR0: 174.16.210.2
LB1: 174.16.211.1
E0: 174.16.215.2
Cisco 1712 E0
Nancho (0X)
SFS1WS DGT III
E-net: 174.16.215.101
SFS1SV DGT III
E-net: 174.16.215.111
0X xxxxxxx General
0X xxxxxxx Audio 8067
0X xxxxxxx ISDN
TCI/
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Div
Sheet 5 of 5