HIGH EFFICIENCY GROUND DATA TRANSMISSION

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In the past, data transmission throughout the NASCOM Network (Figure 1) had been limited to 2400 bits per second per voice bandwidth channel.

This limitation was due to, first, incomplete understanding of the transmission characteristics of the international leased voiceband circuit, and second, overly conservative communication technology in the design of data modulators/demodulators (or modems).

Given that the bandwidth of these voiceband channels is about 2700 Hz, the bandwidth efficiency was only one bit per second per Hz bandwidth. There were two things that motivated us to achieve a higher efficiency, namely: cost effectiveness on expensive international circuits and a real need for higher data rates for support of GSFC spacecraft and the Skylab.

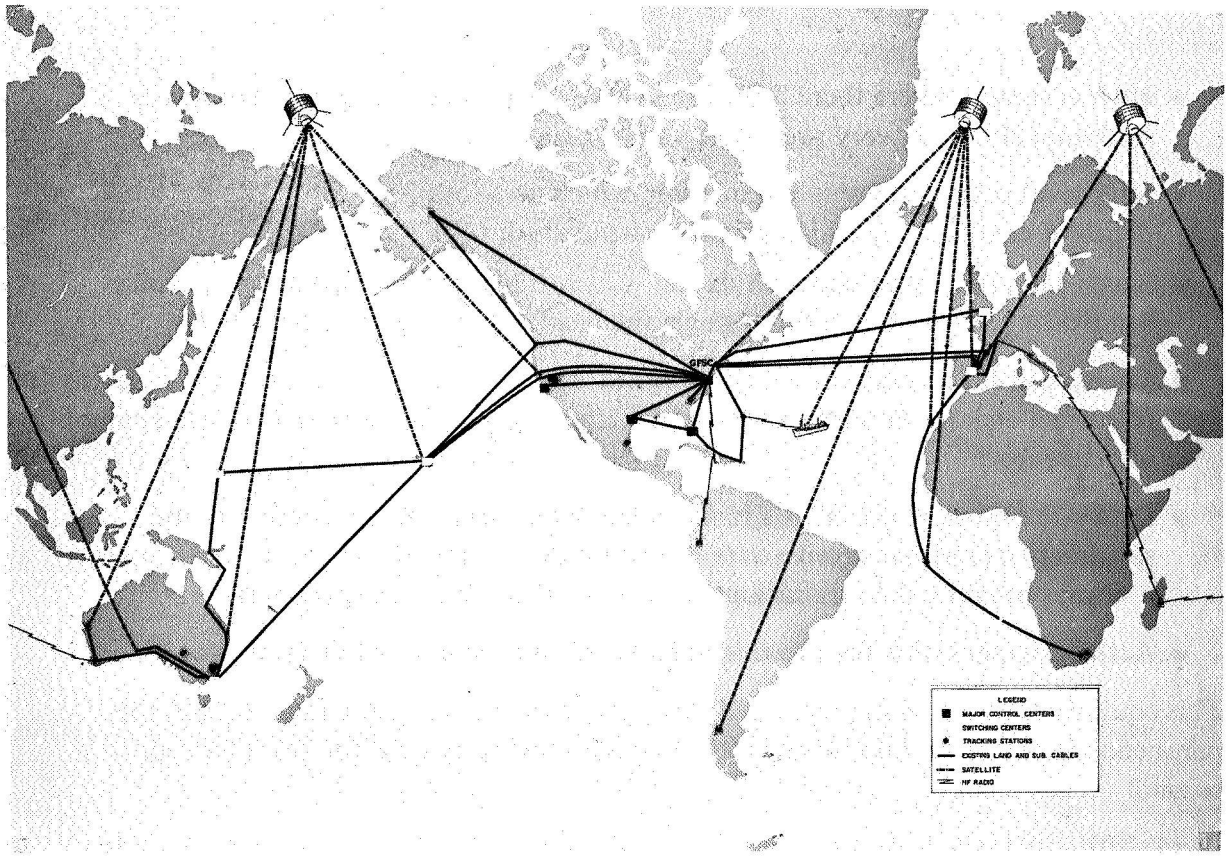

Figure 1. NASCOM network trunking plan.

Recognizing the problem of increasing the voiceband data efficiency, the following approach was taken (Figure 2):

- Initially a program of channel measurement and characterization was instituted

  Width – Amplitude versus frequency response and delay versus frequency response

  Depth – Random noise, impulse noise, and amplitude linearity

  Stability – Incidental modulation (amplitude and angle) signals levels

- Established limits for new parameters and reconfirmed certain existing limits which could be realistically maintained
- Tested various modulation techniques – amplitude, angle (phase modulation, PM mostly)
- Selected the optimum equipment technology
- Implemented and verified performance

Data modem characteristics (Figure 3) determined to be either essential or optimum that is, the best compromise of efficiency and performance for international voice bandwidth channels are:

- High accuracy, where there is precise knowledge of rate in receiver, and where optimum clock recovery procedure can be used
- Multilevel pulse amplitude modulation, which uses four levels, two bits per level, depth of channel, and which conserves bandwidth
- Single-sideband amplitude modulation, which translates data spectrum to voice bandwidth, efficient because of single sideband, and not double sideband
- Transversal filter equalizer, which is an automatic and continuously adaptive device to correct channel amplitude and delay distortion, thereby eliminating intersymbol interference
- Data scrambling, which adds a random-like bit sequence to the send data and substracts it from the receive data to restore the original data stream. In between it always provides data transitions for the equalizer and timing recovery
- Active compensation for phase instability, transmission of a low level pilot tone

This equipment has been implemented throughout the network at a rate of 7200 bits per second in the same voice bandwidth channels previously used for 2400 bits per second.

Bandwidth efficiency is about 3:1 versus the previous 1:1; the level of performance is fully acceptable for all network operations.

It has been demonstrated that state-of-the-art communications technology can be implemented and reliably operated on a global basis and NASCOM is currently the only network now doing this. We are currently pursuing the same line of investigation to increase the transmission rates and efficiencies on circuits with bandwidths greater than the typical speech channel.

- CHARACTERIZE INTERNATIONAL CHANNEL
  - WIDTH
  - DEPTH
  - TIME STABILITY
- ESTABLISH MAINTENANCE LIMITS
- TEST AND EVALUATE MODULATION/DEMODULATION AND CODING TECHNIQUES
- SELECT OPTIMUM EQUIPMENT TECHNOLOGY
- IMPLEMENT AND VERIFY PERFORMANCE

Figure 2. Increase voiceband data efficiency.

- HIGHLY ACCURATE/STABLE DATA RATES ($\pm 1 \times 10^{-5}$)
- MULTI-LEVEL PAM (4-LEVELS)
- SINGLE-SIDEBAND AM
- TRANSVERSAL FILTER (TIME DOMAIN) EQUALIZER
- DATA SCRAMBLING FOR TRANSPARENCY AND CLOCK RECOVERY
- ACTIVE COMPENSATION FOR CHANNEL PHASE INSTABILITY

Figure 3. Data modem features.