AN 11 GHz CONTIGUOUS BAND OUTPUT MULTIPLEXING NETWORK FOR INTELSAT VI SPACECRAFT

T-8

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ABSTRACT

Measured data of a 5-Channel 11 GHz Contiguous Band Multiplexer meeting INTELSAT VI requirements is presented. No compensating networks or dummy channels are used in the physical realization of the multiplexer, thus advancing the state-of-the-art.

Introduction

The five-channel 11 GHz contiguous band multiplexing network described in this paper was developed to satisfy the multiplexing requirements for the proposed INTELSAT VI Spacecraft. This represents an advance over the 11 GHz INTELSAT V multiplexer which combined non-contiguous channels using 4-pole elliptic function filters operating in the TE_{103} propagation mode [1].

Multiplexer Configuration and Optimization

There are two techniques presently available to combine channels on a common waveguide manifold. These are described as follows:

Singly Terminated Network Approach

The classic approach for designing contiguous band multiplexers is based on using a singly terminated lowpass filter as the prototype network to derive the channel bandpass filters [2]. Such filters exhibit impedances for which the real part is nearly unity over the passband, and decreases rapidly to zero outside of it. The reactive part has a substantial value and a negative slope in the passband. When such filters are combined at a common junction in a short-circuited waveguide manifold, the real part of the overall impedance remains essentially unity whereas the reactance part, through cancellations, tends to be zero over the entire multiplexer bandwidth. In such a scheme, the end channels require compensating networks since they do not have channel filters on one side to cancel the reactive component over the entire passband. In practical multiplexers, many empirical adjustments are required to compensate for waveguide junction discontinuities and dispersion in waveguide and coupling irises, and to achieve the proper impedance levels for each channel. This approach has been demonstrated by M.H. Chen et al [3,4,5] of Comsat Laboratories in designing a four channel contiguous band mux at 4 GHz. A similar approach has been used by Ford Aerospace and Communications Corporation in the design of INTELSAT V multiplexers at 4 GHz [6].

Modified Doubly Terminated Network Approach

An alternative design approach, introduced by J.D. Rhodes & R. Levy [7], utilizes the doubly terminated lowpass filter as the prototype for the individual channels. The multiplexer design then modifies the elements in each channel together with the separation between filters along the waveguide manifold (phase lengths) to realize the desired channel response in the multiplexed configuration. It requires no compensating networks for the individual channels but introduces unit elements between the filters and waveguide junction. This implies a small weight and volume penalty but promises a simpler physical structure and tuning of the multiplexer.

Detailed theoretical and practical investigation of these two techniques indicates that:

(i) Singly terminated approach shows reasonable response for the multiplexed channel for cross-over isolations between 3 & 6 dB. As the cross-over isolation increases beyond 6 dB, the channel response tends to deteriorate. For practical multiplexers, reactance networks are normally required [3,6] to compensate for the reactance of the various channels - especially the end channels.

(ii) The modified doubly terminated approach yields good channel response in the multiplexed configuration for cross-over isolation above 10 dB. The multiplexed channel progressively deteriorates as the cross-over isolation is decreased below 10 dB. On the other hand, the use of unit elements between the waveguide junction and channel filters obviates the need for compensating networks (except for the end channels) and provides an excellent means in the practical optimization of the channels in the multiplexed configuration.

In the multiplexer described here, we have combined the advantages of these two design approaches. In addition, the two end channels are based on doubly terminated asymmetrical bandpass filters [8] to compensate for the reactances of the end channels without resorting to dummy channels or compensating reactance networks.

FREQUENCY PLAN

Channel Designation	Channel Frequencies (GHz)	Usable Channel Bandwidths (MHz)
1-2	10.9925	77
3-4	11.075	72
5-6	11.155	72
7-8	11.495	72
9-12	11.6185	150

Engineering Model Multiplexer Configuration

The salient features of the engineering model 11 GHz output multiplexer are as follows:

- Channel filters are 6-pole dual-mode quazi-elliptic designs operating in the TE_{113} propagation mode.
- Channel bandpass filters are derived from singly and modified doubly terminated lowpass prototype networks.
- Filters for end channels 1-2, 5-6, 7-8 & 9-12 are asymmetrical in their electrical response.

  Separation of 340 MHz between channels 5-6 & 7-8 necessitates asymmetrical designs for these channels.
- No compensating networks or dummy channels are used in the physical realization of the multiplexer.
- Multiplexer spacings are optimized using unit elements between the waveguide junctions and channel filters.
- The waveguide manifold does not contain any screws or other tuning elements.

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Measured Data and Conclusions

The photograph of the engineering model appears as figure 1. Measured data is described in figures 2 to 6.

Table 1 gives the measured performance summary of a typical channel. It indicates that all specification requirements are met under the ambient environment.

The multiplexer described here combines the best features of the singly terminated approach, the doubly terminated approach, and the advantages of asymmetrical bandpass filters (for end channels). This, in our considered opinion, represents an advance in the state-of-the-art for microwave multiplexing networks.

Acknowledgements

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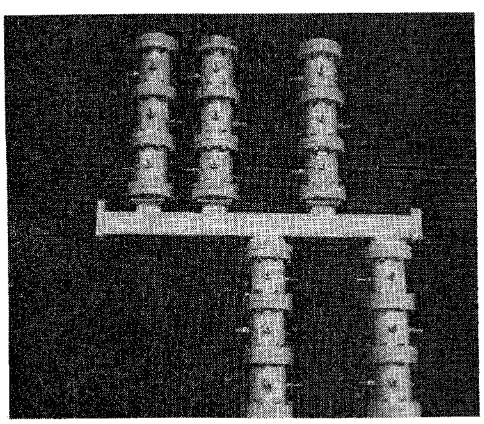

FIGURE 1: PHOTOGRAPH OF THE 11 GHz CONTIGUOUS BAND ENGINEERING MODEL MULTIPLEXER

TABLE 1: MEASURED PERFORMANCE SUMMARY OF A TYPICAL CHANNEL

PARAMETER	CHANNEL 1-2	
	SPECIFICATION	MEASURED RESPONSE
Insertion Loss at f_o, dB	1.0*	.64
Loss Variation over 100% usable BW, dB	0.85	0.70
Gain Slope, dB/MHz		
CF ± 80% usable BW	0.035	0.027
CF ± 90% usable BW	0.07	0.055
CF ± 100% usable BW	0.25	0.166
Group Delay, ns		
CF ± 16 MHz	-1.5/3.4	0/1.5
CF ± 24 MHz	-1.5/9	0/3.7
CF ± 32 MHz	-1.5/16	0/8.5
CF ± 38.5 MHz	-1.5/28	0/18.5
Group Delay Slope, ns/MHz	.2 or 2 x Slope of GD Mask	< 2 x Slope of computed GD Mask
Group Delay Stability, ns	± .5 or ± 15% of GD Mask	< ± 15% of computed GD Mask
Group Delay Ripple, ns	1.0	< 1
Out-of-Band Attenuation		
CF ± 53.5 MHz	25	25.6
CF ± 64 MHz	30	36.7

* This specification includes the multiplexer loss as well as the loss of wideband output isolator and lowpass harmonic filter.

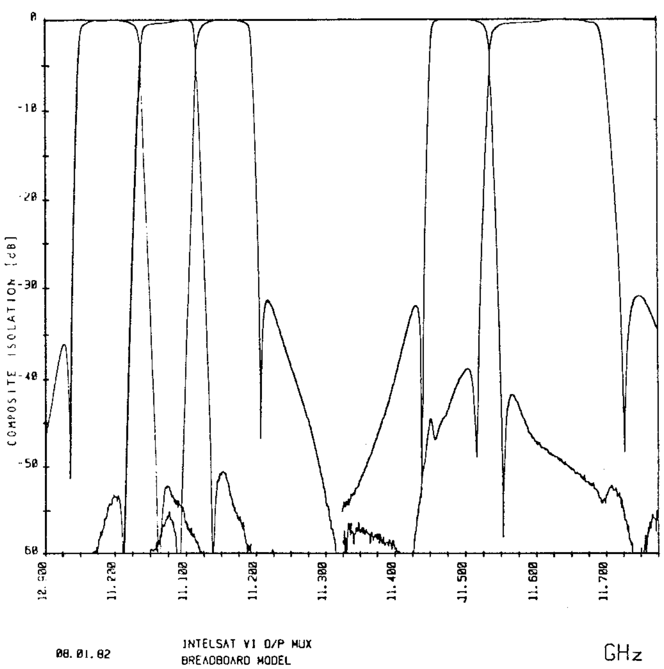

FIGURE 2: MEASURED ISOLATION RESPONSE OF THE FIVE CHANNEL CONTIGUOUS BAND MUX

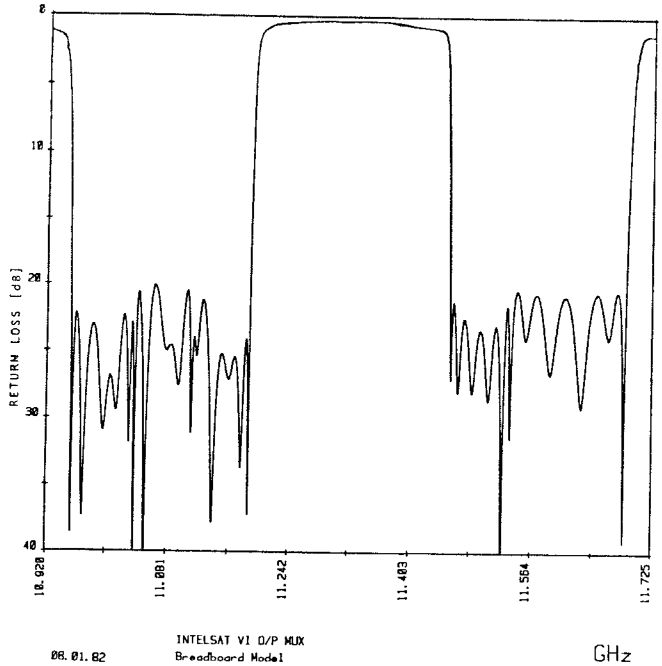

FIGURE 3: MEASURED COMMON PORT RETURN LOSS OF THE FIVE CHANNEL CONTIGUOUS MUX.

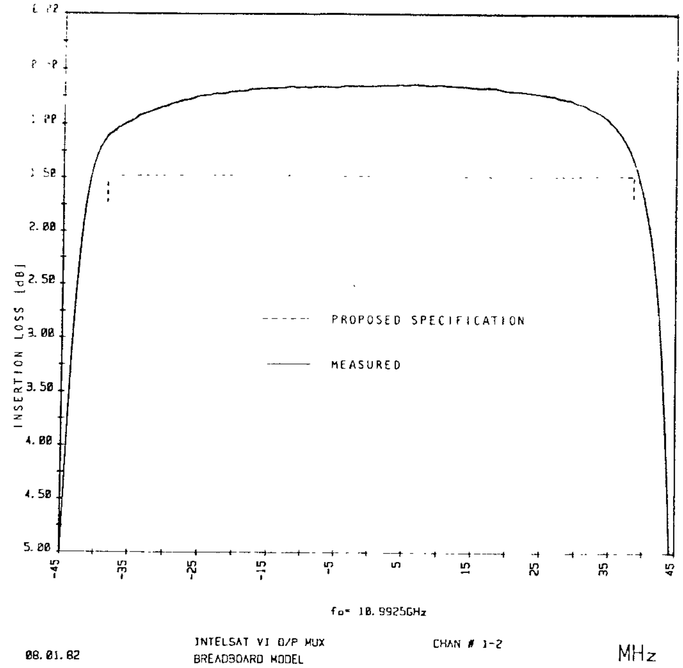

FIGURE 5: MEASURED INSERTION LOSS RESPONSE OF CHANNEL 1-2 IN THE MULTIPLEXED CONFIGURATION.

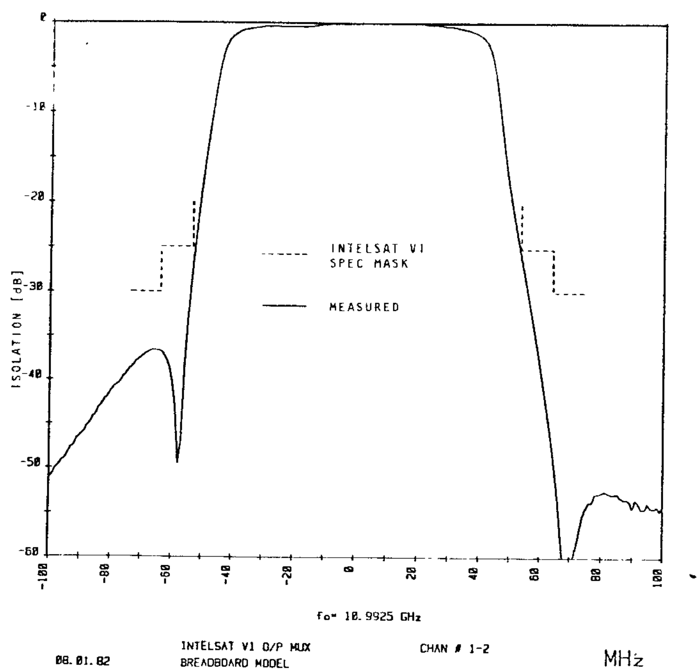

FIGURE 4: MEASURED ISOLATION RESPONSE OF CHANNEL 1-2 IN THE MULTIPLEXED CONFIGURATION.

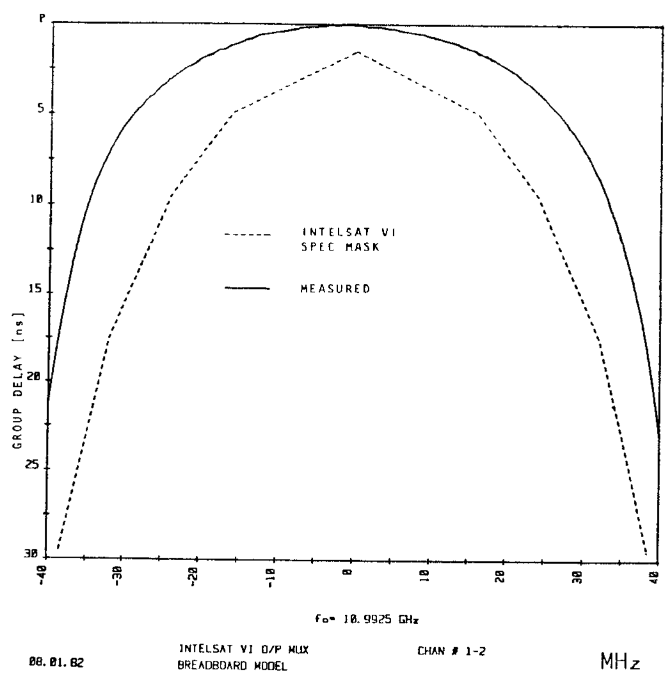

FIGURE 6: MEASURED GROUP DELAY RESPONSE OF CHANNEL 1-2 IN THE MULTIPLEXED CONFIGURATION.