MODELING COMPLEX SIGNALS USING BASIC SIGNAL COMPONENTS

Squadron Leader Dick Delaney, RAF Aldergrove, UK, dickdelaney@hotmail.com
Chris Gorringe, Racal Instruments Ltd, (44) 1202 872800, chris@racalinst.co.uk

ABSTRACT

One of the fundamental problems encountered by test engineers is that of balancing the desire to use standard signal descriptions against the flexibility offered by those tailored to a specific application. This paper looks at a new approach to providing the flexibility of a tailored description but by using standard, mathematically rigorous, building blocks; the aim of this approach is to provide consistent definitions that can be easily recreated on any test hardware possessing the required performance envelope.

Keywords: ATLAS, Signal Description, Reusable, Test Definition, Object orientation.

1 INTRODUCTION

History has shown us that restrictive descriptions have always had to be customized in the field. This paper examines how the new Signal Description and Test Definition IEEE Standard provides a higher level of signal extensibility, allowing new and exciting Signals to be defined using standard building block and extensibility mechanisms. To show the concept, this paper walks through the creation of the Test Signal Framework (TSF) that accompanies the IEEE Signal Definition and Test Description Standard.

2 BASIC SIGNAL COMPONENTS

Basic Signal Components are the fundamental Building Blocks used to describe simple signals. They are derived from mathematically defined components within the Signal Modeling Layer of the standard in order to provide a mathematical underpinning of the characteristics of the signal being created.

Because Basic Signal Components are described using Object Orientated terminology they are categorized into classes according to their characteristics, behavior and interfaces. The Basic Signal Components comprise 4 Base Classes, each of which may have Sub Classes. The Base Classes are presented in the following table:

Table 1 Base Classes

Base Class	*Description*	*Ident*
SignalFunction	base class of all A2K signal generators	1
Signal	allow signal functions to exchange information	2
Resource	defines the available set of A2K signals	3
Physical	real world, dimensioned signal values	4

The first of these classes, SignalFunctions, describe objects that are used for modeling Signals, whilst Signals represent the real world entities that are modeled through the interconnections of SignalFunctions. SignalFunctions can be grouped and interconnected to describe complex signals, these groups are called Signal Graphs, each Signal Graph describing one or more signals. A generalized form of a SignalFunction is shown in the figure below, this shows all the major interfaces and properties.

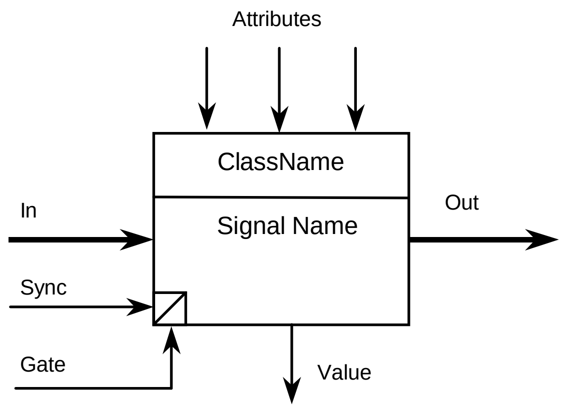

Figure 1 Signal Function Diagram

In a SignalFunction diagram the following naming conventions are used:

ClassName is the name of the A2K Class that the template represents i.e. **ConstantVoltage,** whilst Signal Name is the name of the specific signal being modeled i.e. **DC Signal**.

The SignalFunction has placeholders for several types of Signal interfaces, these being:
In – which is of type reference to Signal, and Sync and Gate – which reference to Events

Out represents the signal interface of the SignalFunction.

A SignalFunction may also have Attributes, which are the controlling properties of the SignalFunction; and Values that represent measurable characteristics of the In signal.

The Sub Classes for the SignalFunction class are:

> **Source.** A Source produces a signal based on the value of the Physical attributes. A Source must create an Out signal and possess at least one Attribute, it supports Gate and Sync events. It does not possess values and does not use any In signals.
>
> **Sensor.** A Sensor observes/records the In signal and will generate values for the specified attribute of that signal. A Sensor must have an In signal and the 'measurement' Value, it supports Gate and Sync but does not create an Out signal.
>
> **Conditioner**. A Conditioner combines one or more commutative input Signals into an associated output Signal, based on the Physical attribute values. A Conditioner must have at least one signal In and will create an Out signal, it supports Gate and Sync events and may possess Attributes but does not possess Values.
>
> **Connection**. A Connection represents a real world collection of pins, through which the In signals pass, or from which any Out signals flow. A connection has both In and Out signals and supports Attributes, Gate and Sync. A Connection does not possess any Values. The principle purpose of a Connection is to identify the real world names of the pin such as “PL1-1” through which the real signal must flow.
>
> **EventFunction**. The EventFunction Class contains Event Sources and Event Conditioners. Event Sources defines Events whilst Event Conditioners allow Event definitions to be modified, based on the action of other Events and Signals. An EventFunction must have an Out property and will possess Attributes, it may have a signal In and will support Gate and Sync events but does not possess Values.
>
> **Control**. The Control Class provides the ability to sequence different signal with a signal model. It provides features such as ManyToOne meaning supply in term these (In) signals to this (Out) SignalFunction, or Sequence, that allows a single signal to be build up from different signal components that are active at different times or after different events.

Complex signals are constructed by combining any number of the available Basic Signal Components provided in the Standard. This ability to create new signals based upon mathematically defined components is the key factor in providing extensibility of signal definition previously unavailable within signal based test description languages.

3 TEST SIGNAL FRAMEWORKS

A Test Signal Framework is a library of reusable, formally described complex signals or ‘Signal Graphs’ developed to describe a specific technology or domain, such as RF, and are used in the development of test requirements relating to that domain. Several TSFs have been created to be included as part of the Standard, these being loosely derived from the signal capabilities of IEEE Std 716-1995 C/ATLAS. Additional TSFs can be created and existing TSFs extended by users to accommodate further complex signals that are not already included in the Standard.

The IEEE Std 716-95 defines 50 signals as Nouns and presents a table of Noun Modifiers to be used with each. Analysis of the Noun Modifiers shows that although some are essential to the basic definition of the signal, i.e. Amplitude and Frequency; many others, such as Crest Factor, would be seldom used in practice. Whilst it would have been possible, when creating TSFs to represent the signals within 716-95, to map the complete functionality represented by the Noun and its associated Noun Modifier table, this approach would have presented an overly complex and unwieldy signal definition, very little of which would be used on a regular basis.

Given that one of the primary purposes of the published TSFs is to provide clear and easily understood examples of signals and to show how signals can be defined and extended to meet specific requirements, the preferred approach when creating the equivalent complex signal has been to present a ‘no frills’ signal that will be useful to most users most of the time whilst allowing them to create their own model based on that in the published TSF to meet the occasional requirement covered by many of the listed Noun Modifiers.

4 DEFINING COMPLEX SIGNALS

The methodology adopted in defining the complex signals within the existing TSFs is illustrated in the following examples. This methodology is reliant upon the person defining a signal having a comprehensive understanding of how that signal would be created in the real world, however, whilst the person defining the signal must understand all of the characteristics of the complex signal and how it comes into being, subsequent users of the TSF do not require the in depth knowledge of the originator but are still able to use the complex signal in a consistent manner with no ambiguity of its characteristics.

4.1 AC Signal

IEEE Std 716-1995 C/ATLAS describes AC Signal as a sinusoidal time-varying electrical potential. The attributes that are considered essential to this definition being Amplitude, Frequency and Phase. Of the functionality provided by the other Noun Modifiers listed for AC Signal, only the ability to define a DC Offset within the ‘core’ signal definition was considered to be a fundamental requirement. The resulting definition of AC Signal can be modeled using just 3 Basic Signal Components: 2 sources, Sinusoid and Constant, whilst the third is a conditioner labeled SUM. These can be connected as shown in the Signal Graph Diagram below

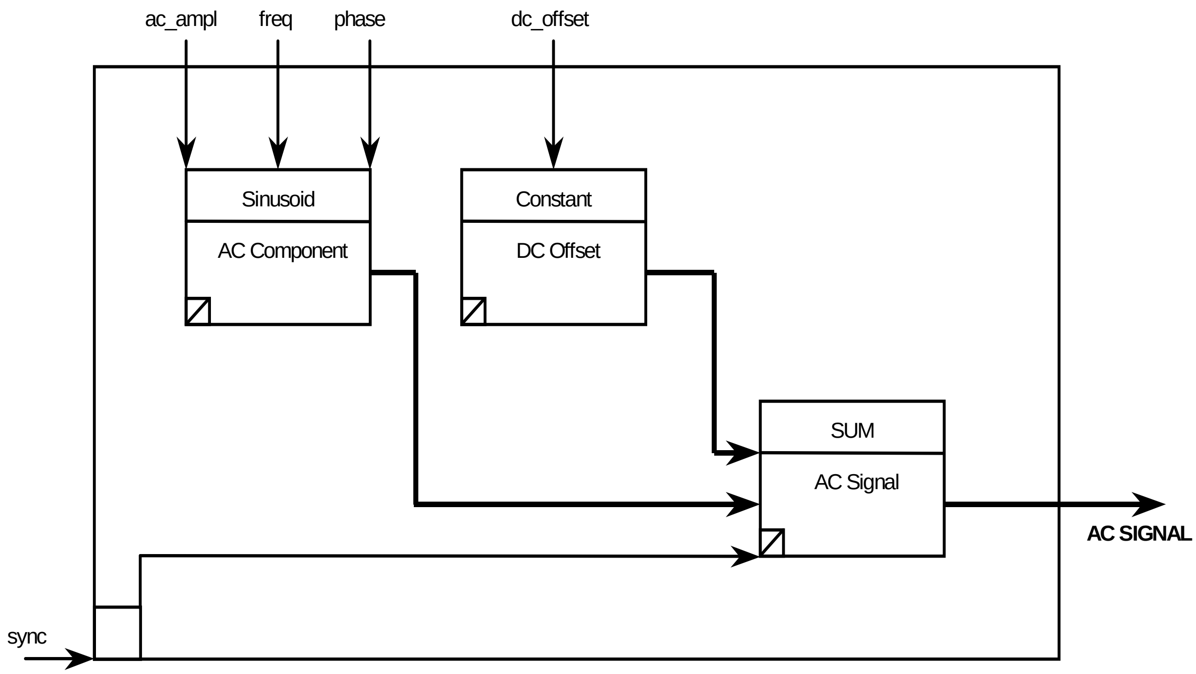

Figure 2 AC Signal

It can be seen that the SUM takes the outputs of both the AC Component and DC Offset and, according to its mathematical definition, arithmetically sums them to produce the AC Signal. Both source components inherit sync event information from the SUM component. Having defined the model it is possible both to fully define the interface properties of the complex signal and to describe it in table format, the format chosen for these tables being shown below.

Table 2 AC Signal Interface Properties

Description	**Name**	**Type**	**Default**	**Range**
AC Signal amplitude	ac_ampl	Voltage | Current | Power		
AC Signal frequency	freq	Frequency	1KHz	0Hz to 1000Hz
AC Signal Phase Angle	phase	Plane_Angle	0	0-2*pi
DC Offset	dc_offset	Voltage | Current | Power	0	

Table 3 AC Signal Model Description

Name	**Type**	**Terminal**	**Inputs**	**Output**	**Formula**
AC Component	Sinusoid<type>	Signal[Out]		AC Component	
		amp	ac_ampl		
		freq	Freq		
		plane_angle	phase		

Name	Type	Terminal	Inputs	Output	Formula
DC Offset	Constant<type>	Signal[Out]		DC Offset	
		amp	dc_offset		
AC Signal	SUM	Signal[Out]		AC SIGNAL	
		Signal [In]	AC Component		
		Signal [In]	DC Offset		
		Sync [In]	Sync		

4.2 SUPPRESSED CARRIER SIGNAL

A Suppressed Carrier Signal is an amplitude modulated signal where both sidebands are present but with the carrier frequency suppressed. This can be modeled quite simply using just 5 basic components

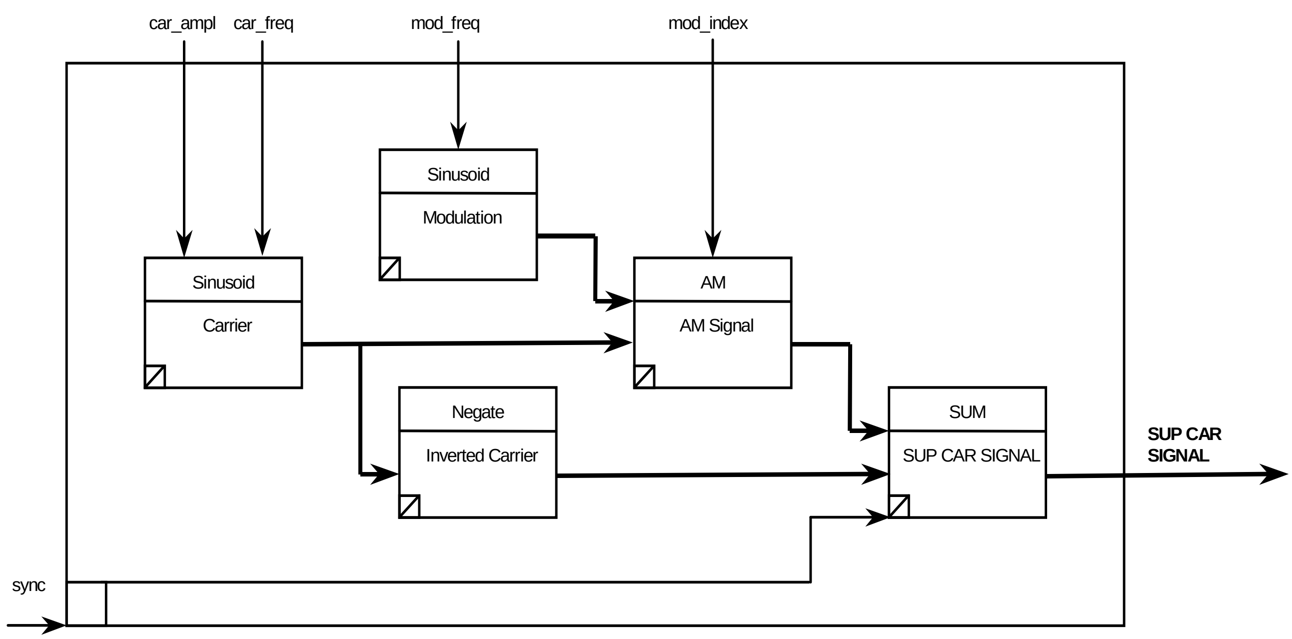

Figure 3 Suppressed Carrier Signal

It can be seen that a simple Amplitude Modulated Signal is created using a Modulator component and 2 Sinusoids, one for the carrier and one for the modulation (although this could be a periodic component other than a sinusoid), and this is in fact the model for AM Signal. The carrier can then be phase reversed and summed with the AM Signal to leave only the sidebands present as the output of the model.

Table 4 Suppressed Carrier Wave Interface Properties

Description	Name	Type	Default	Range
Carrier amplitude	car_ampl	Voltage		
Carrier frequency	car_freq	Frequency		
Modulation frequency	mod_freq	Frequency		
Depth of modulation	mod_index	Ratio		

Table 5 Suppressed Carrier Wave Model Description

Name	Type	Terminal	Inputs	Output	Formula
Carrier	Sinusoid<type>	Signal[Out]		Carrier	
		Amp	car_ampl		
		Freq	car_freq		
Modulation	Sinusoid<type>	Signal[Out]		Modulation	
		Freq	mod_freq		
AM Signal	Modulator(AM)	Signal[Out]		AM Signal	
		ModIndex	mod_index		
Inverted Carrier	Negative	Signal[Out]		Inverted Carrier	
		Signal[In]	Carrier		
SUP CAR SIGNAL	Sum	Signal[Out]		SUP CAR SIGNAL	
		Signal [In]	AM Signal		
		Signal[In]	Inverted Carrier		
		Sync [In]	sync		

4.3 TACAN

TACAN (tactical air navigation) is a complete UHF polar coordinate navigation system using pulse techniques and providing both distance and bearing information. However, because the distance function operates identically to DME, any test requirement dealing with TACAN distance can use the pre-defined DME TSF model. The TACAN model therefore only defines the subset of the TACAN X signal concerned with bearing rather than the complete signal.

The TACAN TSF model needs to model a signal that would normally be created by a ground transponder which transmits RF pulse pairs that are amplitude modulated to provide bearing information. The amplitude modulation is imposed at frequencies of 15 and 135 Hz whilst the pulse pairs are arranged in bursts of 600µsec (Main Reference Burst) and 300µsec (Auxillary Reference Bursts), these bursts being transmitted at 15 and 135 Hz respectively. The airborne receiving equipment would determine the aircraft bearing from the ground station by measuring elapsed time, first, from the MRB to the 0 degree phase of the 15 Hz component and, second, from the ARB to the 0 degree phase of the 135 Hz component.

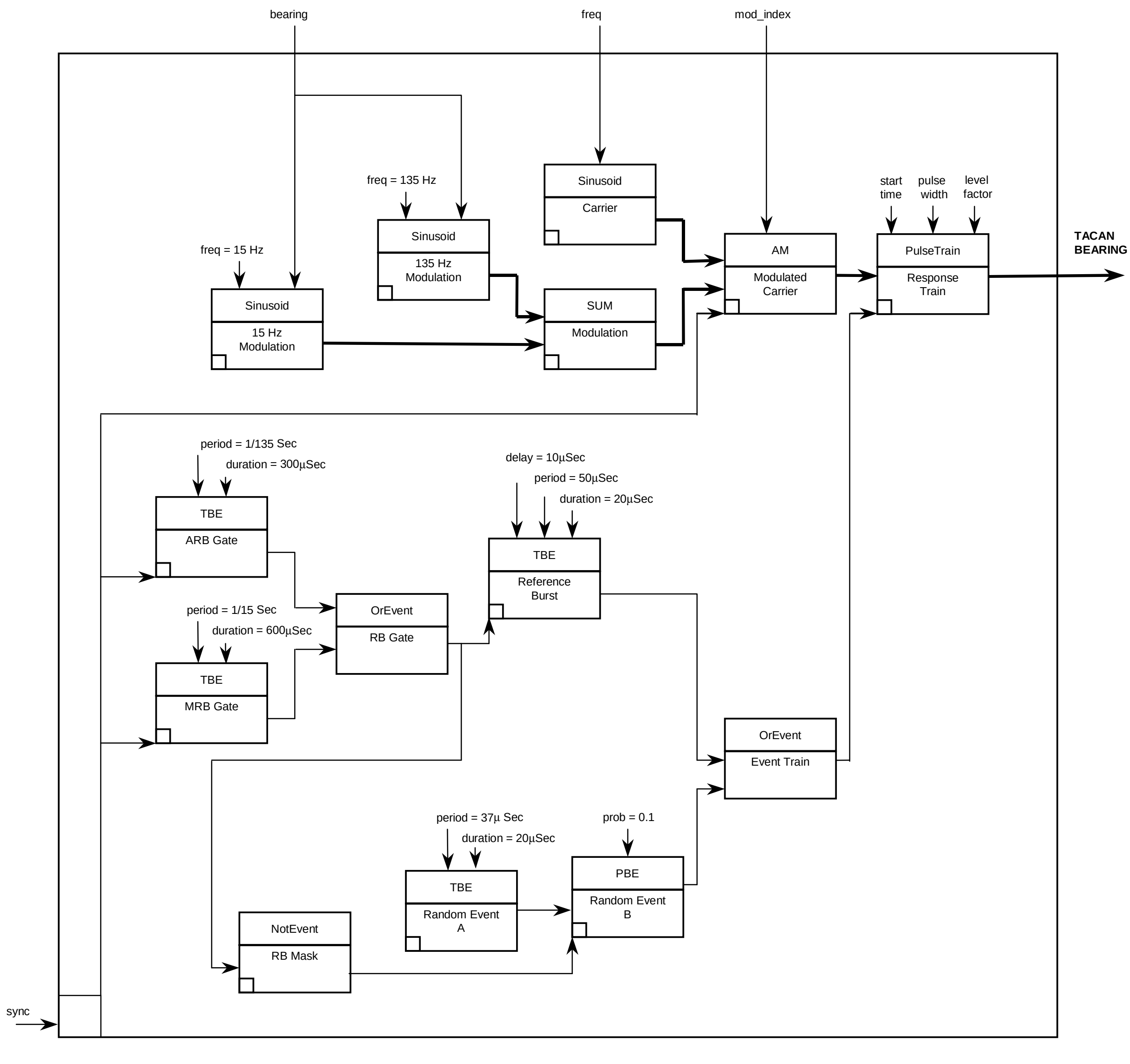

Figure 4 TACAN Signal

Whilst this amplitude modulation is actually produced by rotating a parasitic reflector array about the antenna radiating element, at a rate of 15 times per second, and synchronized with the pattern

of Main and Auxiliary Reference Bursts of pulse pairs; the creation of a model to allow this complex signal to be created with general purpose instrumentation is relatively straight forward. This does however emphasis the need to fully understand the signal before it can be modeled.
As for DME, the transponder generates 2700 pulse pairs per second but with a jittered prf.

It can be seen that many of the attributes relating to the components within the model are effectively defaulted to set values leaving only the attributes of interest, or of unknown value in the case of Modulation Index, to be defined within the test requirement. The Amplitude modulated RF carrier is defined in the top part of the diagram before being fed to a PulseTrain component that creates one pulse pair. This component is synchronized and triggered by each event in an event train representing a combination of randomly generated pulse pair triggers and those comprising the Main and Reference Bursts. The timing protocol for the Reference Bursts is defined in the in the middle part of the diagram, these comprising triggers for 12 and 6 equally spaced pulse pairs respectively, these pulse trains take priority over both interrogator generated and randomly generated pulse pairs, hence the model needs to suppress these at the appropriate time, this is achieved by creating a mask using a NotEvent component and the output of the Reference Bursts, this mask is used as a 'suppressing' gate on the pseudo randomly generated trigger.

Table 6 TACAN Interface Properties

Description	**Name**	**Type**	**Default**	**Range**
Transponder Frequency	freq	Frequency	962 MHz	962 – 1024MHz 1151 – 1213MHz
Modulation Index	mod_index	Numeric	0.3	0 - 1
Magnetic Bearing	bearing	PlaneAngle	90^{o}	0 – 360^{o}

Table 7 TACAN Model Description

Name	**Type**	**Terminal**	**Inputs**	**Output**	**Formula**
Carrier	Sinusoid	Signal[Out]		Carrier	
		Freq	freq		
15 Hz Modulation	Sinusoid	Signal[Out]		15 Hz Modulation	
		Freq			Freq = 15 Hz
		Phase	bearing*		Phase= Bearing*pi/180
135 Hz Modulation	Sinusoid	Signal[Out]		135 Hz Modulation	
		Freq			Freq = 135 Hz

Name	**Type**	**Terminal**	**Inputs**	**Output**	**Formula**
		Phase	bearing*		Phase = Bearing*pi/20
Modulation	SUM	Signal[Out]		Modulation	
		Signal[In]	15 Hz Modulation		
		Signal[In]	135 Hz Modulation		
Modulated Carrier	AM	Signal[Out]		Modulated Carrier	
		Signal[In]	Carrier		
		Signal[In]	Modulation		
		Sync[In]	Sync		
		ModIndex	mod_index		
ARB Gate	TimeBasedEvent	Event[Out]		ARB Gate	
		Sync[In]	sync		
		Period			Per = 1/135 Hz
		Duration			Dur = 300 µs
MRB Gate	TimeBasedEvent	Event[Out]		MRB Gate	
		Sync[In]	sync		
		Period			Per = 1/15 Hz
		Duration			Dur = 600 µs
RB Gate	OrEvent	Event[Out]		RB Gate	
		Event[In]	ARB Gate		
		Event[In]	MRB Gate		
Reference Burst	TimeBasedEvent	Event[Out]		Reference Burst	
		Gate[In]	RB Gate		
		Delay			Del = 10 µs
		Period			Per = 50 µs
		Duration			Dur = 20 µs
RB Mask	NotEvent	Event[Out]		RB Mask	
		Event[In]	RB Gate		

Name	**Type**	**Terminal**	**Inputs**	**Output**	**Formula**
Random Event A	TimeBasedEvent	Event[Out]		Random Event A	
		Period			Per = 37 µs
		Duration			Dur = 20 µs
Random Event B	ProbabilityBased Event	Event[Out]		Random Event B	
		Gate[In]	RB Mask		
		Probability			Prob = 0.1
Event Train	OrEvent	Event[Out]		Event Train	
		Event[In]	Reference Burst		
		Event[In]	Random Event B		
TACAN BEARING	PulseTrain	Signal[Out]		TACAN BEARING	
		Signal[In]	Carrier		
		Sync[In]	Event Train		
		Array of Pulse: (Start Time, Pulse Width, Level Factor)			P1(0, 3.5 µsec,1) P2(15.5 µsec, 3.5 µsec,1)

5 Conclusions

The aim of the paper has been to show how complex signals can be modeled without ambiguity and to demonstrate the extensibility inherent within the standard. By issuing TSFs based upon 716-1995 C/ATLAS it is expected that the majority of signals commonly used will already be defined, however, the way in which these signals are defined and presented should allow test engineers to modify and enhance existing signals or to create entirely new signals. By including these signal definitions in the Test Requirement Definition the signal can be created within any test environment.

6 References

[1] IEEE Std 716-2000 Draft H, March 2002.